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HODGES'
PRACTICAL
CHEMISTRY.

M.WAR
Binders

# PRACTICAL CHEMISTRY.

# FIRST STEPS

IN

# PRACTICAL CHEMISTRY,

FOR

## AGRICULTURAL STUDENTS,

## FARMERS, AND BLEACHERS.

BY

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# PREFACE.

THIS little book is designed to afford agricultural students, engineers, farmers, and persons engaged in bleaching establishments, a concise and simple introduction to the study of practical chemistry. We possess several valuable works on this important department of science, but as these have been written for the use of professional students, they necessarily contain descriptions of processes and of substances which are of comparatively little interest to that class for whose instruction this book is intended. It is therefore believed that by the pupils in Agricultural Schools, and many other persons, the instruction which it affords will be found acceptable. In Agricultural Schools, the Systematic Course for the examination of substances which it describes, may, with much advantage, be made to form a part of the instruction of the more advanced pupils, and will be found to contribute to the development of habits of observation, and also be useful in preparing them for the duties of their future occupation. The plain directions which are given will enable farmers and others to investigate the qualities of soils and waters, and correctly to estimate the value of guano, and the various manures which are employed in this country. The operations necessary for the quantitative analysis of a substance require, in the greater nnmber of cases, an amount of skill and knowledge which cannot be acquired without training in a laboratory, under the guidance of a teacher. I have, therefore, only included in this elementary work directions for the performance of such investigations as may be performed by any intelligent person with ordinary care. A knowledge of the qualities of substances, however, will be sufficient to assist the agriculturist in many important inquiries, and will serve to protect him from imposition in the purchase of manures. Of the advantages to be derived from the kind of knowledge which it is the object of this work to assist in rendering more accessible, De Gasparin, one of the most distinguished of the agricultural writers of France, thus correctly remarks—"That though we cannot expect that the operations of chemical analysis should form a part of the ordinary business of the farmer, yet, that it cannot be too strongly recommended that they should be made to constitute an object of instruction and recreation to such young farmers as have enjoyed the advantage of a liberal education. Such persons will find opportunities of employing them with advantage in their profession, and they will afford them the means of interpreting the varied and curious phenomena which daily pass before them, which are unintelligible to those who have not acquired the habit of interrogating nature, and of noting her operations."

Directions for the performance of the various methods required in alkalimetry have been given, which it is hoped may be found serviceable to the young bleacher and manufacturer.

JOHN F. HODGES.

QUEEN'S COLLEGE, BELFAST,
December 1, 1856.

# OUTLINE
OF THE
# METHODS PURSUED BY CHEMISTS
IN THE EXAMINATION OF THE
# COMPOSITION OF INORGANIC BODIES.

---

1. WHEN an unknown body is presented to a chemist for examination, the first inquiry naturally is,—What are its constituents? The merchant or the miner may, perhaps, wish to know whether a piece of rock contains copper or lead, or some other valuable commercial substance; and the farmer may ask whether a mixture sold to him as manure is capable of yielding phosphoric acid, potash, or any of the essential ingredients of plants. The methods employed for the discovery of *the kind* of substances of which a body of unknown composition consists, constitute an important department of chemical science, termed, from its objects, *qualitative analysis*—and are based upon the knowledge which has been acquired by experience—*i.e.*, by experiment—that by means of certain processes and agents, characteristic alterations may be produced in the appearances, composition, and properties of the constituents of bodies, by which their presence may be recognised. The substances which are used by chemists to produce these characteristic phenomena are called *tests*, or *reagents;* and the alterations or phenomena produced by them on the constituents of bodies, are technically designated *reactions*.

*Illustrations.* 1. Dissolve two or three grains of the common green vitriol of the shops *(a mixture of the proto and per-sulphate of iron)* in a pint of water. The solution will be colourless and transparent; add to it a few drops of the solution of *ferrocyanide of potassium*, and a beautiful blue precipitate will be formed. This reaction is characteristic of the presence of compounds of the peroxide of iron; and the student who, by the addition of the *test*, detects the presence of the compound of the metal dissolved in the water, performs a *qualitative analysis.*

2. Open a bottle of the beverage sold under the name of soda water, and pour its contents into a tumbler. Place in the liquid a strip of *blue* litmus paper. Observe that the colour of the test paper is changed to *red.* This reaction is characteristic of the presence of an *acid.* Hold the reddened paper for a few minutes near the fire; observe that the red colour is removed,—the acid is therefore *volatile.* Pour about a wine-glassful of the soda water into another tumbler, and add to it an equal quantity of transparent *lime water:* the mixture will be rendered *turbid* and *white.* Empty the mixture into the tumbler containing the larger portion of the soda water, and the cloudiness will disappear. These reactions shew that the acid which the beverage contains is a *volatile acid—carbonic acid*—a certain amount of which combines with lime to form a solid compound —*carbonate* of lime—which has the property of dissolving in water when a larger proportion of the acid is added to it.

2. The presence of certain substances having been demonstrated by qualitative analysis, the next question which arises is,—In what proportions do these matters enter into the composition of the body? How much copper or lead does the ore, or how much phosphoric acid or ammonia does the manure contain? The operations and processes which are employed in order to ascertain the proportions by weight, in which the components of a body are contained in it, constitute what is termed *quantitative analysis.*

Though the chemical or agricultural student who has acquired a knowledge of the reactions of the substances which are likely to come before him in his investigations, could, when a solution containing only one of these substances is presented to him, by the application of his tests, ascertain its nature, yet this method of proceeding, though occasionally sufficient when our only object is to discover the presence of a single constituent, as when we add a solution of *potash* to a sample of manure, to ascertain whether it contains *ammonia*, is not in all cases applicable, as the properties of substances are so much modified when mixed with other matters, that their reactions are not, in many cases, to be recognised. It is necessary, therefore, that some plan should be adopted which may not only enable us to bring the various constituents of a body into a proper state for the exhibition of their characteristic reactions, but by which we may obtain a knowledge of *all* the substances present, and also be certain that no constituent of the body has been overlooked. For this purpose, the progressive system of investigation pursued in the School of Chemistry in the University of Giessen, formerly under the direction of Baron von Liebig, assisted by Professor H. Will, is admirably adapted. By this method, which is now generally adopted, we are able, by the addition of a few tests, to arrange all the constituents of a compound or mixture into *groups* or *classes*, distinguished by certain common peculiarities; and then, by the application of special reagents, we can proceed to the examination of the individual members of each group which may be present. In the first place, the attention of the student is directed to the discovery of the metallic oxides *(bases)* contained in the compound; and this is effected, not by adding the tests at random, but in a definite, systematic order, so as to obtain evidence of the presence or absence of certain groups of these bodies. This method of analysis, therefore, "consists in adding to the solution of a compound consisting of five or six, or more constituents, successively, other substances which enter into combination with one or other of these constituents, forming insoluble compounds. This is done in a certain definite order, just as if each constituent was contained in a different drawer, the opening of which required a particular key appropriated to itself."*

In the systematic examination of the metallic oxides, the substances, as shown in the following table, are arranged in five groups, by the successive employment of HYDROCHLORIC ACID, SULPHURETTED HYDROGEN, AMMONIA, SULPHIDE OF AMMONIUM, and CARBONATE OF AMMONIA. These substances, therefore, serve as *general* or *classifying reagents*.

---

* Liebig.

## 8. SYSTEMATIC ARRANGEMENT OF THE METALLIC OXIDES IN GROUPS.

GROUP I. The distinctive characteristic of this group is, that all its members are precipitated from their solutions by HYDROCHLORIC ACID.

It contains *silver*, *protoxide of mercury*, *and lead;* but as *lead* is not separated completely by the general reagent, it may also be found in the next group.

GROUP II. The distinctive characteristic of this group is, that all its members are precipitated from their *acid* solutions by SULPHURETTED HYDROGEN.

It contains *copper*, *bismuth*, *antimony*, *tin*, *arsenic*, *lead*, *peroxide of mercury*, *gold*, *platinum.*

GROUP III. The distinctive characteristic of this group is, that all its members are precipitated from their *neutral* solutions by SULPHIDE OF AMMONIUM; but are not precipitated by SULPHURETTED HYDROGEN from their solutions, when rendered *acid* by mineral acids, (*hydrochloric acid*, &c.,)

It contains *aluminium*, *chromium*, *cobalt*, *nickel*, *iron*, *zinc*, *manganese*, and also *phosphates of alumina*, *baryta*, *lime*, *strontia*, *magnesia.*

GROUP IV. The distinctive characteristic of this group is, that all its members are precipitated from their solutions by CARBONATE OF AMMONIA; but are not precipitated by HYDROCHLORIC ACID, SULPHURETTED HYDROGEN, nor by SULPHIDE OF AMMONIUM.

It contains *baryta*, *strontia*, *lime*, *magnesia.**

GROUP V. The distinctive characteristic of this group is, that the substances contained in it are *not precipitated from their solutions by any of the general reagents*, so that its members may remain dissolved in a solution, from which all those of the preceding groups have been removed.

It contains *potash*, *soda*, *ammonia.*

---

* See (58. *E.*)

# APPARATUS AND REAGENTS

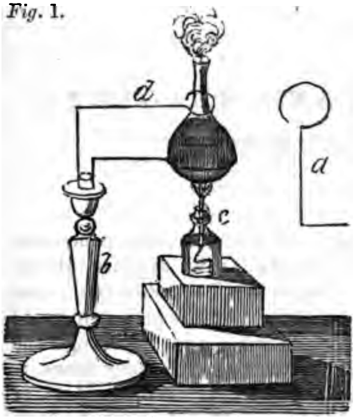
## REQUIRED BY THE STUDENT.

4. A SMALL SPIRIT LAMP. An excellent and economical spirit lamp, may be formed by taking a bit of glass tube an inch long, and about the thickness of a goose quill, and passing it through a hole bored in a cork, which is inserted into the neck of a common glass ink-bottle. Through the tube, a piece of cotton wick, doubled three or four times, is drawn, and the portion projecting from the upper part of the tube cut off smooth about a quarter of an inch above the tube. It is then merely necessary to pour some spirits of wine into the bottle, to insert the cork, and to apply a light to the projecting wick, and a spirit lamp is ready to give its heat for any purpose for which it may be necessary to use it. If a piece of a glass tube is not accessible, a bit of tin plate may be used to form the wick-holder.

5. A RETORT-STAND. As a substitute for the ordinary retort-stands and funnel-holders, I some time ago suggested the adoption in rural schools, and by young farmers, of the following arrangement, which will serve not merely to sustain a piece of glass over the flame of a lamp in experiments with manures, but may be adopted to support vessels of various kinds, such as Florence oil flasks, &c., in obtaining solutions, by boiling substances in water or acids. It can be constructed in a few minutes in any farm-house where there is a piece of thin iron wire. For this purpose, it is merely necessary to take a bit of wire seven inches long, and to bend one end of it into a ring about an inch and a-half in diameter, and about two inches from the other end to bend the wire again at a right angle. (*fig.* 1. *a.*) Having given the wire the proper shape, fit a cork into the top of a candlestick, and force the straight end of the wire into the space between it and the side of the candle-holder. Thus arranged, the projecting ring on the wire affords an excellent

support for small vessels, and may, it is obvious, be made of any size required, the weight of the iron or brass candlestick rendering it steady. By means of blocks of wood placed under it, the spirit lamp (4) may be raised so as to give the substance supported on the ring any degree of heat desired. To steady Florence flasks while exposed to heat, two wire rings may be advantageously used, upon one of which the flask may be placed; while a second ring, with the upright stem of sufficient length, may be made to surround the neck of the flask. (*fig.* 1. *d.*)

*Fig.* 1.



6. Test tubes of German glass :—2 dozen will be required ; 1½ dozen of which should be six inches in length and three-fourths of an inch in diameter.

7. Test tube frame.

8. Half a dozen glass funnels, (*fig.* 3. *d.*) of different sizes, from three to eight inches diameter.

9. A few porcelain capsules, capable of containing each about half an ounce of liquid.

10. A porcelain crucible, capable of containing two ounces of liquid.

11. Two porcelain evaporating dishes ; one capable of containing about six ounces, and the other about two ounces of liquid.

12. A small procelain mortar and pestle.

13. Glass rods, for stirrers, and some pieces of glass tube of the diameter of an ordinary quill, which, when softened over the flame of the spirit lamp, may be bent so as to form conducting tubes for gas bottles, &c.

14. A few Florence flasks and glass beakers (*fig.* 3. *e.*)

15. Apothecaries' balance and weights.

**16. Filter Paper.** As the method of preparing paper filters may not be known to some young students, the following directions may be useful :—The common white blotting paper sold by stationers may, in many cases, be employed, but for analytical processes it will be advisable to procure a paper free from the impurities which common papers usually contain. Paper suitable for the purpose may be had from dealers in chemical apparatus. To form a filter you have merely to cut a circle (*fig.* 2.) of the porous paper, and to fold it in half, and then to double it again, so as to bring the four corners together. Next separate the outer fold from the others, so as to produce a conical cavity, and place the paper so prepared in a glass funnel somewhat deeper than the little cone formed by the filter. The liquid to be filtered is poured upon the filter, the funnel containing which may be supported by means of the wire-holder described above, and the liquid received in any convenient vessel. The drawing (*fig.* 3) shows the form of a support, and the usual arrangement adopted in the Laboratory, for the separation of liquids from precipitates, &c.

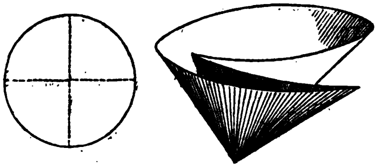
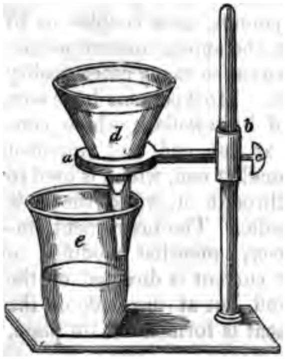


*Fig.* 2.



*a.* Ring to support the funnel.
*d.* Filter.
*e.* Beaker used to receive the filtered liquid.

*Fig.* 3.

17. A BLOW-PIPE, and a few pieces of good charcoal. (*see* 20.)

18. CORK CUTTERS, or ROUND FILES, to form holes in corks, for the insertion of tubes, &c.

19. A WATER BATH, or apparatus for drying substances by exposure to the heat of boiling water. The water bath of the chemist, like the glue pot of the carpenter, consists of a double vessel, with water placed in the outer vessel, while the substance to be dried is placed in the inner vessel and exposed to the heat of the water, maintained at the boiling temperature. The apparatus is heated by the fire, or over a lamp, until the weight of the substance, after being removed and weighed, and again heated for some time and weighed, is found to remain constant. A common tea-kettle, or a saucepan, with the lid inverted, so as contain the substance to be dried, forms an excellent water bath. The illustration shows an arrangement for the purpose (*fig.* 4). The simple wire support described may be used to support the bath above the spirit lamp.

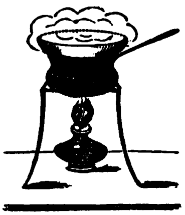


*Fig.* 4.

## USE OF THE BLOWPIPE.

20. The blowpipe is a simple instrument of great value in the examination of mineral compounds, as it enables us to produce characteristic changes in the appearances of metals and their compounds, by which we can in many cases readily and rapidly ascertain their nature. Most persons have seen the common brass blowpipe used by jewellers, which consists of a tapering tube curved at one end, and provided with a very fine opening at the smaller end, which is used to direct a current of air blown through it, while the jet is placed close to the flame of a candle. The instrument employed by the chemist is, however, somewhat modified in shape, the jet through which the current is directed on the flame, being placed, not at the end, but at one side of the tube. The body of the instrument is formed of tin plate,

and the lateral tube is provided with a small brass jet. The effects of the flame produced by the blowpipe blast are different, according to the portion of it to which the substance is exposed. Thus, the outer portion of the jet of flame, where the air blown into it and the oxygen of the atmosphere produce complete combustion of the inflammable gases, exerts an *oxidizing* influence, while the inner blue cone of flame which may be observed surrounded by the yellow oxidizing flame, and in which carbonaceous matters only partially consumed exist, has a *reducing* effect, depriving metallic compounds submitted to it of oxygen. The point of the flame at which reduction is most readily effected is just beyond the apex of the inner blue flame. These qualities of the different portions of the flame must be borne in mind. In our references to them, we shall use the terms *outer* and *inner flames*, to designate the oxidizing and reducing portions of the flame. By a little practice, the method of keeping up a continuous steady flame, without fatigue, may be acquired by the student.

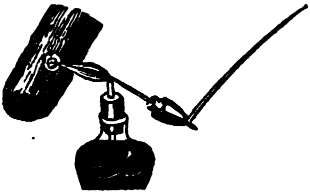


*Fig.* 5.

In situations where the ordinary blowpipe is not to be obtained, an excellent substitute for it may be formed by closing the bowl of a common clay tobacco pipe (*fig.* 5) with a cork, through which a piece of glass tube about two inches in length is to be passed, a hole sufficient to allow of its insertion being cut with a round file. One end of the tube, previous to its being fixed in the cork, should be softened in the flame of the lamp and drawn out, and then cut across with a file so as to leave an aperture not larger than will admit a fine sewing needle, or if a glass tube is not at hand, a piece of the stem of a pipe with a sufficiently fine orifice may be fixed in the cork, and will serve to form the jet of the blowpipe. By means of this simple instrument, and the flame of the ink-bottle spirit lamp (4), or even of a common tallow candle, the ordinary operations of blowpipe analysis may be successfully performed.

## REAGENTS.

21. Hydrochloric acid (*muriatic acid*) is one of the most indispensable solvents, and an important reagent. Its freedom from impurities should be carefully ascertained, as the ordinary commercial acid (*spirit of salts*) is unfit for the purposes of the chemist. The acid employed in analysis may be examined as follows:—A drop of it evaporated on a slip of glass should leave no residue. *Chloride of barium* solution added to a portion of it, diluted with six times its bulk of distilled water, should produce no precipitate (*absence of sulphuric acid*). A portion of it diluted with water and rendered alkaline by the addition of *ammonia*, and again made acid by the addition of *acetic acid*, should not be rendered blue when mixed with a few drops of solution of *ferrocyanide of potassium* (*absence of iron*). When boiled with a few drops of solution of *sulphate of indigo*, the blue colour of the test should not be destroyed (*absence of free chlorine*).

22. Ammonia, solution of. One part of caustic ammonia diluted with six parts of water.

23. Sulphuretted hydrogen, solution of. This reagent is prepared by saturating distilled water with the gas obtained by acting upon sulphuret of iron by sulphuric acid diluted with water. The most simple apparatus for this purpose consists of a half-pint bottle provided with a cork, through which a bent glass tube is inserted, as shown in the drawing (*fig.* 6). The longer limb of the tube, however, should not be curved, but proceed down in a straight line from the angle which it forms with the horizontal portion. About half an ounce of sulphuret of iron, broken into fragments, should be placed in the bottle, and some sulphuric acid (*oil of vitriol*), diluted with eight parts of water, introduced. The cork, with its tube, should then be inserted, and the gas received in a bottle containing distilled water. The solution thus prepared may be used as a reagent; or the gas may be directly employed for the same purpose, by allowing it to

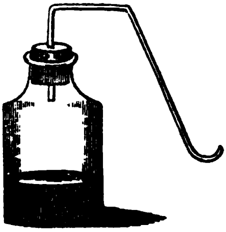


*Fig.* 6.

pass from the exit tube into the liquid to be examined. As the solution of the gas, however, soon spoils by keeping, it is recommended that the student should fit up a small bottle, or a test tube furnished with a bent tube, and prepare small quantities of the gas as he may require it in his operations.

24. SULPHIDE OF AMMONIUM. This reagent is prepared by a process similar to that just described for the preparation of the solution of sulphuretted hydrogen, substituting for the distilled water used to receive the gas, solution of ammonia (22). The gas should be passed into the solution, until the liquid, when mixed with a few drops of solution of *sulphate of magnesia*, ceases to yield a precipitate.

25. CHLORIDE OF AMMONIUM, solution of. Made by dissolving one part of the crystals in six of water. If pure, it will entirely volatilize when heated on a slip of glass exposed to the flame of the lamp.

26. CARBONATE OF AMMONIA, solution of. Prepared by dissolving one part of the commercial salt in four of water, and adding one part of liquid ammonia.

27. OXALATE OF AMMONIA. A saturated solution of the salt is used.

28. PHOSPHATE OF SODA, solution of. Prepared by dissolving one part of the commercial salt in six parts of water.

29. TARTARIC ACID, solution of. One part of the acid dissolved in six parts of water.

30. CARBONATE OF SODA, is required both in the dry state and in solution in water.

31. HYDRATE OF LIME. Prepared as required, by slaking fresh lime with water.

32. FERROCYANIDE OF POTASSIUM, a saturated solution of.

33. SULPHATE OF MAGNESIA, a saturated solution of.

34. CHLORIDE OF BARIUM, a saturated solution of.

35. LIME WATER, a saturated solution of freshly burned lime.

36. BARYTA WATER, a saturated solution of caustic baryta.

37. NITRATE OF SILVER, solution of. It is formed by dissolving one part of the crystals in eight parts of water.

38. CHLORIDE OF CALCIUM, solution of. One part of the salt dissolved in three parts of water.

39. PERCHLORIDE OF IRON, solution of. Formed by

adding a sufficient amount of the reagent to water to yield a solution of a light sherry colour.

40. ACETATE OF LEAD, solution of. One part of the salt in ten parts of water.

41. BICHLORIDE OF PLATINUM, solution of

42. NITRATE OF COBALT, solution of.

43. ACETATE OF POTASH, solution of. One part of the salt dissolved in eight parts of water.

44. ALCOHOL.

45. DISTILLED WATER. Its freedom from the impurities which ordinary water contains, should be examined by the methods described at (63). A portion of it evaporated in a porcelain capsule should leave no residue.

46. NITRIC ACID. It should leave no residue when evaporated to dryness; and the absence of sulphuric acid and hydrochloric acid should be ascertained by diluting the acid with six parts of water, and adding to one portion *chloride of barium*, and to another portion *nitrate of silver*,—no precipitate nor cloudiness should be produced.

47. NITRO-HYDROCHLORIC ACID. Formed as required, by adding one part of nitric acid to four parts of hydrochloric acid.

48. SULPHURIC ACID (*oil of vitriol*). A drop of the liquid when evaporated should leave no residue. It usually contains *sulphate of lead*, which may be removed by diluting it with six times its bulk of water, and decanting the clear liquid from the deposit which takes place when it is allowed to rest. On being tested for *nitric acid*, as described (at 61. *g.* and *h.*) it should afford no indication of its presence. *Arsenic*, is occasionally contained in the commercial oil of vitriol; its presence may be detected, and its removal effected, by saturating the acid, diluted as above-directed, with sulphuretted hydrogen; which will produce with it a yellow precipitate. The subsidence of the precipitate will be facilitated by allowing the mixture to stand for some time in a warm place. It should then be filtered, and the filtrate boiled to drive off the sulphuretted hydrogen.

49. SOLUTION OF INDIGO, prepared by heating one part of indigo with seven of concentrated sulphuric acid, and diluting the solution with water until it has merely a pale blue colour.

50. ACETIC ACID should, if pure, entirely volatilize when heated on a piece of glass, and should not be rendered turbid on the addition of *chloride of barium*, *nitrate of silver*, or of *sulphuretted hydrogen.* When mixed with a few drops of *solution of indigo*, and boiled, it should not discolorize it.

51. NEUTRAL CHROMATE of POTASH, solution of. Prepared by dissolving one part of the salt in ten parts of water.

52. POTASH (*caustic potash*) solution of. The potash sold by dealers in chemicals is seldom free from impurities, and frequently contains sulphuric acid, silicic acid, alumina, and chloride of potassium. It also rapidly attracts carbonic acid from the air, and should, therefore, be preserved in closely stoppered bottles, and its solution prepared only in small quantities at a time, by dissolving the solid potash in water. The solution may be tested as follows:—*Lime water* added to it should not render it turbid (*absence of carbonic acid*). Portions of it rendered acid by the addition of an excess of nitric acid, should afford precipitates neither with *chloride of barium* nor with *nitrate of silver* (*absence of sulphuric acid, chlorine, and chloride of potassium*). Upon saturating a portion of the solution with *hydrochloric acid,* and evaporating to dryness, the residue should entirely dissolve in hydrochloric acid (*absence of silica*); and on adding an excess of *ammonia* to the acid solution obtained, no precipitate should be produced (*absence of alumina*).

53. CARBONATE OF POTASH AND SODA. Mix together four parts of dried carbonate of potash and three parts of dried carbonate of soda, and preserve the mixture in a bottle. Used to convert silicates of the alkaline earths and other compounds insoluble in water and acids, into forms suitable for examination.

54. RED, BLUE, and NEUTRAL LITMUS PAPERS.

The apparatus described, and also pure reagents, may be obtained from the dealers in chemicals in large towns; in Belfast from Grattan & Co., and Aickin; in Dublin, from Robinson, Grafton-street; and in London, from Simpson & Maule, Newington-crescent, &c.

REMARK—That in all cases where the term "water" is employed in the directions given for analytical processes, distilled water is meant; and the reagents directed to be used, unless where it is otherwise stated, are understood to be in solution.

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## PRELIMINARY EXAMINATION OF THE SUBSTANCE.

55. The substance, the composition of which you are required to investigate, may be either A SOLID—a piece of rock, an ore, a metal; or A SOLUTION.

If THE SUBSTANCE IS A SOLID, the student, in proceeding to ascertain its nature, should, in the first place, carefully examine its physical properties—its weight, specific gravity, colour, hardness, shape, lustre, &c., and make a few simple experiments on it, in order to discover its relations to heat, water, acids, &c., which may serve to give him some idea of its composition, and also direct him in the course most suitable for its complete analysis.

I. Its *weight and lustre* will show whether it is a pure metal or not.

II. Its *specific gravity*, the degree of *hardness* which it exhibits, and the colour of the mark or *streak* which it produces when rubbed on paper, when conjoined with the observation of the effects produced upon it by exposure to the heat, will usually be sufficient to indicate its nature.

The *specific gravity* of substances insoluble in water, may be determined in the following manner: Procure a bottle of light glass, with a long neck, capable of containing about 1½ oz. of water, and by means of a file, scratch a mark on the neck. Set the bottle on one of the pans of the balance, and counterpoise it by placing pieces of sheet lead or shot, contained in a pill-box, on the other pan. Fill it up to the mark with distilled water, the temperature of which should be, as nearly as possible, 60° F., and by placing weights on the pan which contains the counterpoise, ascertain the weight of the water introduced. The water is then to be emptied out, and a convenient quantity of the substance broken into pieces sufficiently small, and weighed, is to be introduced; and water is again to be poured into the bottle until the fluid reaches exactly to the mark on the neck, and all moisture having been wiped from the outside, it is again weighed. It will be obvious that the water now contained in the bottle will be less by a quantity equal to the bulk of the substance, and the *specific gravity*, or relative weights of equal bulks of the specimen, and water, which is taken as the standard of comparison, may be readily found by a simple calculation—

| | |
|---|---|
| Suppose the weight of the bottle filled with water to be, ... ... ... ... | 500 grs. |
| Weight of the substance introduced, ... | 100 |
| | —— |
| Weight of the whole, had no water been displaced, ... ... ... ... | 600 |
| Observed weight of both, ... ... | 560 |
| | —— |
| Difference, representing the weight of the water displaced, equal in bulk to the substance ... ... ... ... ... | 40 |

Then $\frac{100}{40}=2{\cdot}5$, the specific gravity of the substance.

The *specific gravities* of the earthy minerals range from 2·0 to 4·5, while those of the metallic ores are above 5·0.

III. *Hardness.* The method of ascertaining the hardness of a mineral is to cut it with a knife or steel file, and to compare the resistance which it offers with that exhibited by some other mineral of known hardness. The following scale of degrees of hardness has been proposed by a distinguished German mineralogist, which, when the minerals named are accessible, may be used.

1. Talc.
2. Gypsum.
3. Calcareous Spar.
4. Fluor Spar.
5. Apatite.
6. Adularia.
7. Rock Crystal.
8. Topaz
9. Corundum.
10. Diamond.

A more generally useful comparative scale has, however, been devised,* which will enable the student at all times exactly to estimate the degrees of hardness of the specimens which he may examine.

1. The substance yields easily to the nail.
2. Yields with difficulty to the nail, or merely receives an impression from it. Does not scratch a copper coin.
3. Scratches a copper coin, but is also scratched by it, being about the same degree of hardness.
4. Not scratched by a copper coin. Does not scratch glass.
5. Scratches glass, though rather with difficulty, leaving its powder on it. Yields readily to the knife.
6. Scratches glass easily. Yields with difficulty to the knife.
7. Does not yield to the knife. Yields to the edge of a file, though with difficulty.

8, 9, 10. Harder than flint.

2·5 scratches a copper coin slightly, and 3·5 is scratched by one in about the same degree.

IV. A few grains of the substance, reduced to powder, should be introduced into a narrow glass tube† about three inches long, and open at both ends, and heated over the flame of a spirit-lamp with a small wick, and the changes, if any are produced, noted.‡

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* By Mr. Chapman, whose *Practical Mineralogy* may advantageously be consulted by the student who wishes to obtain further information on the recognition of minerals.

† The glass tubes used for this operation should be purchased from chemical dealers, and must be formed of glass free from lead. The hard potash glass manufactured in Germany is admirably adapted for all chemical purposes. They should be about three inches long, and one-eighth of an inch in diameter. The substance should be placed about half an inch from one end of the tube, which, during the operation, should be held with that end where the specimen is placed, somewhat below the level of the part supported by the hand.

‡ If the body be a mineral, a magnifying glass should be used to ascertain whether it be *homogeneous*, *i.e.*, whether it consists of the same substance throughout. If composed of mineral particles of different kinds, as in granite, these should, if possible, be picked out and separately examined.

*a.* If the substance *blackens*, the presence of ORGANIC matters is shown.

*Note.* If the substance blackens, the presence of organic matters is *almost* certain; there are, however, some organic substances which are not blackened, and also a few inorganic bodies which are rendered almost black (*oxide of bismuth, oxide of mercury*), when heated.

*b.* If it *detonates* or *deflagrates*,* it contains both ORGANIC matters and NITRATES, or CHLORATES.

*c.* If the substance, when heated, evolves a peculiar odour which is—

*aa.* Like *burning sulphur*,—SULPHUR or a SULPHIDE is present.

*bb.* Like *garlic*,—ARSENIC is present.

*cc.* Like *head salts* (ammonia),—it contains a NITROGEN COMPOUND.

*d.* If it *entirely volatilizes*, with or without depositing a solid coating (*a sublimate*) on the cool parts of the tube, it probably consists either of a compound of AMMONIA, MERCURY, ANTIMONY, or ARSENIC, and it is, of course, unnecessary to search for *potash, soda*, and other non-volatile substances.

*e.* If a part *remains fixed*, and on the heat being continued, either fuses, or remains unchanged:

*aa.* If it *fuses*, and if on adding a bit of paper to the fused mass, and again heating, deflagration is produced, it may contain NITRATES or CHLORATES. If *deflagration* does not ensue, and if a drop of hydrochloric acid allowed to fall on the mass (the tube being previously allowed to cool), produces an escape of gas, note its smell.

*Note.* If the gas is almost *inodorous*, it is CARBONIC ACID, which was originally present in combination with an *alkali*, or *alkaline earth*, or if, on adding a few drops of hydrochloric acid to a portion of the unaltered substance from which the specimen in the tube was taken, no effervesence follows, the carbonic acid evolved has been produced by the decomposition of an organic acid (*tartaric acid*, *oxalic acid*, *&c.*) of the compound when heated, forming carbonic acid, which enters into combination with the alkali, or alkaline earth, present.

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* From the Latin word *deflagro*, to burn. Place a small bit of saltpetre upon a piece of burning charcoal or turf, and observe the vivid *deflagration* produced.

If the gas evolved possesses, 1. An odour *like rotten eggs*, and produces a black stain on a piece of paper moistened by a solution of acetate of lead, the substance contains a *sulphuret;* 2. *Like chlorine*, it contains a *peroxide*, probably of iron, or manganese.

*bb.* If the part which remains fixed is colourless and infusible, it may contain SILICA, ALUMINA, or an ALKALINE EARTH.

V. Mix about the size of a grain of wheat of the substance, in powder, with twice its bulk of *carbonate of soda*, and add water so as to form a stiff paste; which collect on the point of a penknife, and insert in a small hole, not more than one-eighth of an inch deep, and one-quarter of an inch in diameter, formed on the surface of a piece of charcoal. (*Fig.* 5.) Expose the mixture to the *inner*, or *reducing flame*, of the blowpipe, and observe whether—

*a.* A distinct *globule*, or *bead of metal*, is formed, which occurs when the substance contains TIN, COPPER, SILVER, or GOLD.*

*b.* Or merely a slag-like mixture of reduced metal, and carbonate of soda, which may denote the presence of IRON, NICKEL, or COBALT.

*c.* Or a coloured *incrustation* is formed on the surrounding portion of the charcoal.

*aa.* If *an incrustation*, of a *yellow* colour when warm, *white* when cold, is produced, ZINC is present.

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* Frequently when a small amount of metal is mixed with a large quantity of other substances, no distinct globule is produced, and the finely divided particles of the metal cannot be perceived. The mass should, therefore, be treated as follows:—

Carefully scrape off with a knife the fused mass, and the portion of charcoal surrounding it, and grind it to a fine powder in a small porcelain or agate mortar, and pour some water upon the *bb.* If at all temperatures the incrustation is *white*, ANTIMONY is probably present.

*cc.* If *yellow* or *brown*, LEAD or BISMUTH.

*d.* If an infusible mass, of a white colour, is left on the charcoal, which, when strongly heated, becomes luminous, OXIDE OF ZINC, ALUMINA, or an ALKALINE EARTH, is probably present.

NOTE.—*Reducible metals which form volatile oxides, and* PRODUCE AN INCRUSTATION *on the charcoal.*

ANTIMONY yields brittle grains of metal, evolves a bluish green flame, and forms a *white* incrustation.

BISMUTH yields brittle grains, with an incrustation the colour of which is *orange* while hot, *lemon yellow* when cold. The grains, when pressed under the pestle, flatten, but at the same time break. Does not colour the flame.

ZINC does not yield any pure metal; produces an incrustation, which is *yellow* when hot, *white* when cold. When the residue on the charcoal is moistened by a few drops of solution of cobalt, and again heated, it assumes a *green* colour.

LEAD yields soft easily flattened globules of metal and a *yellow* incrustation, and produces a dark streak when rubbed on paper.

*Reducible Metals,* WHICH PRODUCE NO INCRUSTATION.

TIN, COPPER, SILVER, GOLD, IRON, COBALT.

*Substances which* NEITHER FUSE NOR AFFORD REDUCIBLE METALS.

ALUMINA, MAGNESIA, LIME, STRONTIA, BARYTA;—Carbonates of Strontia and Baryta *fuse.*

SILICA *fuses*, and produces a transparent colourless bead.

VI. Twenty or thirty grains of the original substance are introduced into a test tube, and solution of *potash* or *milk of lime* added, and the mixture heated. Observe whether pungent fumes are evolved, which render reddened litmus

powder so as to wash away the charcoal and soluble matters. Repeat the washing several times, allowing the mortar, after every addition of water, to remain at rest for a second or two, and carefully decant off the suspended matters, and examine the residue. If the substance contained any reduced metal, it will be found either in the form of finely divided particles, or in metallic films adhering to the bottom of the mortar. Soft malleable metals (*lead or tin*) will be observed pressed into flat discs, and the red scales of *copper* can readily be recognised, even when any exceedingly small amount of metal is present. The nature of the reduced metal can, if required, be confirmed by the methods directed for the examination of *metals and alloys.* (55. VIII.)

paper exposed to them *blue;* and which, when a glass rod moistened by hydrochloric acid is brought near the mouth of the tube, produce with it *white clouds.* These reactions are characteristic of the presence of AMMONIA in the substance.

### VII. THE SUBSTANCE TO BE EXAMINED IS A SOLUTION OF UNKNOWN COMPOSITION.

Its qualities are to be investigated as follows :—

*a.* Evaporate a portion of it to dryness in a basin, to ascertain whether it contains any fixed solid matters. If a fixed residue is left, submit it to the operations described for the examination of solid substances. (55. IV.)

*b.* Ascertain, by means of blue and red litmus papers, whether the solution be *acid*, *alkaline*, or *neutral.*

*c.* If it is *acid*, it contains either a free acid, a soluble salt of some of the heavy metals, or an acid salt. Moisten a glass rod with solution of *carbonate of soda*, and introduce it into a small portion of the unknown liquid, placed in a test tube. If on stirring the rod in the liquid a permanent cloudiness is produced, some salt of a heavy metal is present; but if the solution remains clear, or the cloudiness disappears, an acid salt, or some free acid, is contained in it.

*d.* If the solution is *alkaline*, it may contain a free alkali—*potash*, *soda;* an alkaline earth—*baryta*, *strontia*, *lime*, *magnesia*, or an alkaline carbonate or sulphide. If alkaline carbonates are present, it cannot also contain carbonates of the alkaline earths.

*e.* If it is *neutral*, it cannot contain free acids, nor alkalies, nor acid salts; and the only bodies present will be the salts of POTASH and SODA, and of the ALKALINE EARTHS.

### VIII. THE SUBSTANCE PRESENTED FOR EXAMINATION IS A METAL OR AN ALLOY.

Suppose the student has reason, from the results of the examinution of the physical characters (55. I.) of the substance, to conclude that it is either a metal or an alloy, its nature may in general be correctly inferred from the following experiments :—

*a.* Place a portion of the substance, reduced to powder, in a tube with some *nitric acid*, and heat over a lamp. If it wholly dissolves, neither GOLD, PLATINUM, ANTIMONY, nor TIN are present, and the nature of the substances in the solution may be determined by the methods directed in the Systematic Course (58).

*b.* If the substance does not wholly dissolve, and a *white powder* separates on heating with *nitric acid*, which does not disappear on the addition of water, it may contain ANTIMONY or TIN. The powder is to be examined as follows :—

*aa.* Allow it to subside in the tube, and decant off the liquid, which, if found, on evaporation, to contain any dissolved matters, may be examined as directed at (58). Wash the deposit by agitation with water two or three times, and add to it a solution of *tartaric acid*, and boil. If it entirely dissolves, ANTIMONY alone is present.

*bb.* If a residue remains, dry it, and mix it with some *carbonate of soda*, and heat on charcoal before the reducing flame of the blow-pipe, and examine the results of the operation, as directed at (55. V.)

*c.* If the substance is not altered by the action of nitric acid, but dissolves in *nitro-hydrochloric acid*, it may contain either GOLD or PLATINUM.

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## PREPARATION OF THE SUBSTANCE FOR SYSTEMATIC EXAMINATION.

56. The substance submitted to examination, if a solid, must be brought into solution. The solvents employed for this purpose, are either *water*, *hydrochloric acid*, *nitric acid*, or *nitro-hydrochloric acid*. Usually when the student has acquired some experience, the preliminary examination of the substance will be sufficient to point out the proper solvent required; but in the case of many compound bodies—minerals, soils, &c.—in which it is desirable to ascertain the forms of combination in which the constituents of the substance are present, it will be necessary to submit

them to the successive action of water and acids, and also in certain cases, when these agents fail in effecting complete solution, to decompose the insoluble residue by fusion with an alkaline carbonate, &c., by which its constituents are converted into soluble compounds. (*See* 59.)

*a.* In the first place, about 20 grains of the substance, reduced to a fine powder, are to be placed in a test tube, with about a table spoonful of water, and boiled over the lamp for a few minutes. If the substance has been found to contain organic matters, the detection of the fixed bases present will be facilitated by previously exposing the powder to heat, in a small porcelain capsule (9) until the blackness which is produced (by the separation of the charcoal) has entirely disappeared. If the substance does not entirely dissolve, by filtering a few drops of the liquid and evaporating to dryness on a slip of glass, it will be seen whether any solution has been effected. If no residue, or merely a slight stain is left on the glass, it will be unnecessary to preserve *the watery solution* for examination. If, however, a considerable residue is left on evaporation, the liquid is to be poured off, some more water added, and the boiling repeated, and having allowed the insoluble matters to subside, the supernatant clear liquid is to be decanted from the deposit, or filtered, if necessary, and added to the former solution.

*b.* Introduce about a teaspoonful of *hydrochloric acid* into the tube which contains the matter insoluble in water, and repeat the boiling and examination of a portion of the liquid, when the substance does not wholly dissolve. If much residue is left on the glass, the boiling should be continued for some minutes, and the solution filtered from any undissolved matters, and mixed with five times its bulk of water, and divided into two portions, —one of which is to serve for the detection of the metallic oxides (*Systematic Course*, 58. A), while the other is to be reserved for the examination for the acids which may be present (*Systematic Course*, 61). If, from the results of the preliminary examination, there is reason to suspect that the substance contains SILVER or LEAD, concentrated *nitric acid* should be substituted for hydrochloric acid in effecting the solution.

*c.* If a residue insoluble in hydrochloric acid is left, it should be washed several times, by agitating it with water, and decanting off the liquid, and boiled with *concentrated nitric acid;* or, where nitric acid has previously been employed, with hydrochloric acid. If the acids, used separately, fail to effect the complete solution of the substance, *nitro-hydrochloric acid* should be tried (1 part nitric, 4 hydrochloric acid). If this liquid does not dissolve the residue, it probably consists either of *sulphate of lime*, *sulphate of baryta*, or *sulphate of strontia*, or of *insoluble silicates* or *chlorides*, and must be submitted to a special examination by the process described at (59.)

## GENERAL DIRECTIONS.

57. Having, by the application of the means described, brought the substance into solution, the student may either submit each solution to a separate analysis, for which purpose the methods described in the systematic course (58) are to be adopted, or if his only object is to ascertain the nature of the substances present, without reference to the forms of combination in which they exist, he may considerably abridge the labour of his investigation by the adoption of the following plan of proceeding with the solutions obtained. Thus, suppose the body under examination to be a complex mixture of several bases, which require for their solution the successive employment both of water and the acid solvents, he may add to the watery solution an excess of *hydrochloric acid*, which, if *lead*, *silver*, or *protoxide of mercury* is contained in it, will produce a white precipitate, which should be separated by the filter, and its nature ascertained by the methods directed in the Systematic Course (58. A.) The filtered liquid (or the watery solution in which hydrochloric acid has produced no precipitate) should be added to the mixed acid solutions of the compound, and if a precipitate should follow its addition, the mixture must be gently heated, and the undissolved matter separated by filtration, and washed and set aside for further examination, as directed at (59). The mixed solutions should then

be placed in an evaporating dish, and evaporated until the greater portion of the liquid is expelled, and then diluted with four or five times its bulk of water, and the examination proceeded with as follows :—

*a.* Introduce about a teaspoonful of the solution into a test tube, add a few drops of *hydrochloric acid* and solution of *sulphuretted hydrogen*, until the liquid, after the tube has been closed by placing the thumb on the mouth, and agitated briskly, still evolves a strong smell of the gas. If a precipitate is formed, heat the tube gently, by which its deposition will be promoted, and pour it upon a filter supported over a test tube. Reserve the filtered liquid—which in future we shall term the *filtrate* —for examination,[*] and place another tube under the funnel, and wash the precipitate until a drop of the liquid collected on a slip of glass and evaporated to dryness leaves no residue. The wash water may be thrown away.

*Note.* When the first portion of the filtrate is separated from the precipitate, add to it some more solution of sulphuretted hydrogen, to ascertain that all the substances (GROUP II.) which yield precipitates with that reagent have been completely thrown down.

*b.* If it does not remain clear, replace the solution in its tube, add more of the test, heat, and add it to the precipitate already collected on the filter. If it remains clear, the filtration may be proceeded with, and two or three drops of the filtrate should be evaporated, to ascertain if any substances in addition to those separated by *sulphuretted hydrogen* are present.

*c.* If a fixed residue is left on evaporation, it shows that the filtrate still contains other matters, and *ammonia* should be added to it, until, after being agitated, it is found alkaline when tested by red litmus paper. Should the addition of ammonia produce a precipitate, it is not to be regarded, but *sulphide of ammonium* in excess should be added, which will precipitate the members of GROUP III.

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[*] If merely a milky appearance is produced on adding the sulphuretted hydrogen, it depends on the separation of *sulphur* by the action of the acid on the reagent.

present; heat gently, filter, and wash the precipitate and examine the filtrate as already directed; and if necessary, as shown by the evaporation of a portion of the filtrate, continue the analysis.

*d.* Add to the filtrate *carbonate of ammonia* and *chloride of ammonium*, by which all the members of GROUP IV. with the exception of MAGNESIA, will be precipitated, on applying a gentle heat to the liquid.

*e.* Filter, &c., with the precautions already mentioned, and add to a portion of the filtrate, or to the liquid in which carbonate of ammonia has produced no precipitate, *phosphate of soda* and a few drops of ammonia, and agitate briskly for some time; if a white crystalline precipitate is formed, *magnesia* is present. If *magnesia is not present*, a portion of the filtrate from the precipitate thrown down by carbonate of ammonia should be evaporated to dryness, and the residue heated strongly until all ammoniacal salts are driven off. If a fixed residue, soluble in water, remains, POTASH and SODA are present. If MAGNESIA *is present*, it is necessary for the detection of the members of GROUP V. that it should be removed by the process described (at 58. *E. c.*).

1. Do not add more than is sufficient of each reagent; and in employing acids to dissolve precipitates, add the solvent drop by drop, and apply heat, so as not to use more than is absolutely necessary for the purpose.
2. Ascertain carefully by the methods indicated, that the members of each group have been completely removed by the reagents employed, before proceeding to examine for those of the succeeding groups.
3. Do not neglect to wash the precipitates thoroughly, so as to remove any traces of the members of other groups which might adhere to them.
4. Let the tubes, funnels, &c. used, be perfectly clean.
5. Note down the various phenomena observed; and when leaving off work for the day, place labels on any solutions, &c., which may remain over for examination.

## ILLUSTRATION OF THE SYSTEMATIC COURSE

### FOR THE SEPARATION AND IDENTIFICATION OF ALL THE SUBSTANCES CONTAINED IN THE SOLUTION.

58. *A*. HYDROCHLORIC ACID added to the solution* gives a *white precipitate*. Members of GROUP I. are therefore present; LEAD, PROTOXIDE OF MERCURY, or SILVER.

Place the filter containing the precipitate over a test-tube, and pour boiling water two or three times over it.

*a*. Add to the filtrate *dilute sulphuric acid*. If a *white precipitate* is produced, LEAD is present.

*b*. Pour a few drops of *ammonia* over the precipitate remaining in the filter, and receive the ammoniacal liquor in a test tube:

If the *precipitate is blackened*, MERCURY is present.

*c*. Render the ammoniacal filtrate from (*b*.) slightly acid, by adding to it *nitric acid*. If a *white precipitate* is produced, which dissolves on the addition of an excess of ammonia, SILVER is present.

*B*. To the filtrate from *A*, or to the solution in which hydrochloric acid has produced no precipitate, SULPHURETTED HYDROGEN is added, until the liquid, even after agitation, smells strongly of the gas:

*a*. If *no precipitate* is produced, none of the members of GROUP II. are present, and the student may proceed as directed at *C*.

*b*. If a *precipitate* is formed, the solution may contain LEAD, or COPPER, and also the other members of GROUP II., but the consideration of these is omitted, as they are not likely to occur in the examinations undertaken by the young student. Wash the precipitate until a drop of the filtrate gives no precipitate with nitrate of silver, and introduce it into a test tube, and dissolve by heating, with *dilute nitric acid.* Divide the solution into two portions;—to one portion,

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* If *hydrochloric acid* has been employed in the preparation of the solution, it will, of course, be unnecessary to search for the members of Group I., and the student may proceed as directed at *B*.

1. Add a drop of *sulphuric acid*, and if a white precipitate forms after some minutes, LEAD is present.

2. To the second portion, add a drop of solution of *ferrocyanide of potassium;* a mahogany-coloured precipitate shows that COPPER is present.

*Confirming* TESTS:

COPPER. Dilute a portion of the solution of the precipitate in nitric acid, with three or four times the quantity of water, and suspend in it a common sewing needle; allow it to remain for an hour or two, when, if copper be present, the needle will be found coated with a red deposit of that metal.

LEAD. Add to a portion of the solution of the precipitate, *chromate of potash*,—a rich yellow precipitate shows LEAD.

*C.* If the evaporation of a few drops of the liquid from which the members of GROUP II. have been separated, leaves a fixed residue, boil the entire filtrate until it no longer smells of sulphuretted hydrogen; next add a few drops of strong *nitric acid*, and evaporate to dryness—(if the preliminary examination has indicated the presence of organic matter, heat the dish to redness,)—moisten the residue with hydrochloric acid, and after allowing it to remain a few minutes, add three or four times the quantity of water, and dissolve by the assistance of a moderate heat. If an insoluble residue of a white colour remains, it is *silica* (it may possess a reddish tinge from the presence of some peroxide of iron). Filter the solution from the residue (if any remains), render it alkaline by *ammonia* (ascertain its alkalinity by red litmus paper), and add to a portion of it *sulphide of ammonium* in excess. If *no precipitate is produced*, the solution does not contain any of the members of GROUP III., and the examination is to be proceeded with as directed at *D.*

If *a precipitate is formed*, the whole of the liquid is to be treated with *ammonia* and *sulphide of ammonium*, (a precipitate may fall on the addition of ammonia, which, however, is not to be regarded,) and heated. The precipitate is to be collected on a filter and well washed with water to which a few drops of sulphide of ammonium have been added. The first portions of the filtered liquid being reserved for further examination, as directed at *D.*

I. *Examination of the precipitate produced by sulphide of ammonium*, which may contain, of the substances likely to occur in ordinary cases, IRON, MANGANESE, ZINC, ALUMINA (and when the solution of the substance has been effected by an acid solvent, also the *phosphates of the alkaline earths* and *phosphate of alumina*). Place the precipitate in an evaporating dish, and dissolve by heating with *nitro-hydrochloric acid*, and, if necessary filter, and dilute with water; add to the solution an excess of *caustic potash* or *caustic soda*, and again boil the liquid. Ascertain by litmus paper that the solution is strongly alkaline.

*a.* If a precipitate is formed, which remains undissolved on boiling the mixture, it may contain IRON, MANGANESE, and PHOSPHATES OF LIME, and MAGNESIA. Separate the precipitate from the liquid by filtration, and reserve the filtrate for examination, as directed at II. The washed precipitate is to be examined as follows:—

*b.* Place a small portion of it on platinum foil, and add to it a few grains of *nitrate of potash* and *carbonate of soda*, and heat strongly in the outer flame of the blowpipe. If it be rendered of a *green* colour, MANGANESE is present.

*c.* Warm some *dilute hydrochloric acid* in a test tube, and pour it over the remaining portion of the precipitate on the filter so as to dissolve it. Add to the solution *chloride of ammonium* and excess of *ammonia*, and filter; the precipitate collected on the filter may contain the PHOSPHATES OF THE ALKALINE EARTHS and IRON, while the solution will contain any MANGANESE (*b.*) present.

*d.* Dissolve the washed precipitate from (*c.*) in *hydrochloric acid*, and to a *small portion* of the solution add a little *tartaric acid*, and excess of *ammonia*, (filter if necessary) and render acid by the addition of *acetic acid*, and add a drop of solution of *ferrocyanide of potassium*. If a *blue precipitate* is formed, PEROXIDE OF IRON is present.

*e.* Add to the rest of the solution of the precipitate from (*c.*) *acetate of potash* in excess, and *perchloride of iron*, so as to render its colour red; boil until the red colour of the liquid disappears, and filter while hot. The filtrate will contain THE ALKALINE EARTHS which were combined with the PHOSPHORIC ACID; their presence may be detected by examining the solution as directed for the detection of the members of GROUP IV. at *D*.

*aa.* Dissolve the washed precipitate contained in (*e.*) in dilute *hydrochloric acid*, and add *ammonia* and *sulphide of ammonium* in excess, and again boil and filter; and test for PHOSPHORIC ACID, which, if present, will be contained in the filtrate, by adding to it a few drops of solution of *sulphate of magnesia*, and a drop of *ammonia*, and three or four drops of *chloride of ammonium;* agitate briskly, and if PHOSPHORIC ACID be present, a white crystalline precipitate will be produced. If a precipitate does not immediately appear, the liquid, after being strongly agitated, should be allowed to rest for some time, and again examined.*

II. The solution filtered from the precipitate produced by *caustic potash*, may contain ALUMINA, ZINC, OR PHOSPHATE OF ALUMINA; add to it an excess of acetic acid:

*a.* If an insoluble residue is left, PHOSPHATE OF ALUMINA is present.† To the solution filtered from the undissolved residue, add an excess of ammonia, and apply heat.

*b.* The production of a gelatinous precipitate shows that ALUMINA is present. Filter and add *sulphide of ammonium* to the filtrate.

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* For the detection of very minute quantities of phosphoric acid, the following process may be adopted, which, however, requires considerable care in its application:—Dissolve some *molybdate of ammonia* in nitric acid, adding enough of the acid to obtain a clear solution, and drop into the liquid a portion of the solution of the precipitate suspected to contain phosphoric acid, and boil the mixture, when, if phosphoric acid be present, the liquid will acquire an intense yellow colour, and after some time deposit a yellow precipitate, insoluble in hydrochloric acid. As the precipitate is only produced in the presence of an excess of molybdic acid, a very small amount of the solution supposed to contain phosphoric acid should be added to the reagent.

† A a confirming test, dissolve the precipitate in hydrochloric acid, and add a portion of the solution to *molybdate of ammonia*, dissolved in nitric acid, as above directed.

*c.* A white precipitate shows that the liquid contains ZINC.*

*D.* The members of GROUPS I., II., and III., existing in the compound having been removed as directed, the filtrate from the precipitate produced by *sulphide of ammonium* is to be examined for the presence of substances belonging to GROUPS IV. and V. If, on evaporating a few drops of the liquid on a piece of glass or platinum foil and heating strongly over the lamp, *no fixed residue* is left, there is no occasion to continue the analysis. If a *solid residue remains*, add to a small portion of the solution, *carbonate of ammonia*, and apply heat. If a precipitate appears, heat the whole filtrate in the same manner. If *carbonate of ammonia* has not produced a precipitate, there merely remains the examination for MAGNESIA, which is not thrown down down by the general reagent from solutions containing *chloride of ammonium*, and for the members of GROUP V.

*a. A precipitate is formed.* It may contain BARYTA, STRONTIA, or LIME. Filter and wash the precipitate, reserving the filtrate for examination, as directed at *E.* Pour some water on the filter, and add dilute hydrochloric acid in small portions at a time, so as to dissolve the precipitate, and divide the solution into two portions :

*aa.* To one portion add a few drops of *sulphate of potash. No precipitate is produced.* BARYTA and STRONTIA are absent, and the precipitate consisted entirely of LIME.

*Confirming Test.* Render a portion of the solution in hydrochloric acid (*a.*) neutral by the addition of ammonia, and add a few drops of *oxalate of ammonia.* If LIME be present, a white precipitate will be produced.

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* The precipitates (*b.*) and (*c.*) should be washed from all traces of alkali, and the nature of the substances *confirmed* as follows :— Heat a portion of the precipitate on a piece of charcoal before the blowpipe, allow it to cool, and moisten it with *solution of cobalt*, and heat it again to redness. The precipitate (*b.*) if it contains *alumina*, will be rendered of a rich *blue* colour ; the precipitate (*c.*) if *zinc* be present will be rendered *green*. The student should recollect that the substance moistened as directed with *solution of cobalt* should be only strongly *heated*, but *not fused*. This precaution is necessary, as minerals which contain lime, and other substances, when *fused*, produce a blue colour with the reagent, but not while merely heated with it ; while alumina, by being merely heated to redness, gives the distinctive *blue* colour.

*bb.* If *sulphate of potash produces a precipitate,* BARYTA or STRONTIA is present, and LIME may also be contained in it. In such cases, add an excess of *sulphate of potash* to the solution, and boil for some time, and filter from the precipitate, which will contain all the BARYTA and STRONTIA present,* and add to the filtrate *oxalate of ammonia,* when, if LIME be present, a *white precipitate* will be formed.

*E. Examination for* MAGNESIA. Having ascertained the presence or absence of the other members of GROUP IV., it is necessary to examine the filtrate from the precipitate thrown down by *carbonate of ammonia,* or the liquid in which that reagent has produced no precipitate, for MAGNESIA, which cannot be separated by the general reagent from solutions to which *hydrochloric acid* and *ammonia,* or *chloride of ammonium* have been added in the course of the investigation.

*a.* Place about a fourth of the filtrate in a test tube, and add to it *phosphate of soda,* and a few drops of *ammonia,* and agitate briskly. If a *white crystalline* precipitate is formed, MAGNESIA is present.

*Confirming Test.* Evaporate to dryness a portion of the liquid to which no *phosphate of soda* has been added, and heat till ammoniacal fumes cease to be evolved. Place a piece of the residue upon a slip of charcoal, and heat before the blowpipe flame, and when cold moisten by *solution of cobalt,* and again heat. The production of a *pale rose* colour is characteristic of MAGNESIA.

*b.* If MAGNESIA is not present, the reserved portion of the liquid is to be evaporated to dryness, and strongly heated, so as to drive off the ammoniacal salts, the residue dissolved in a little water, and examined for POTASH and SODA—all the substances belonging to the preceding groups having been removed by the reagents employed; and the presence or absence of AMMONIA in the compound having been determined by the preliminary examination. (Operation VI.)

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* Place a portion of the precipitate on a piece of platinum foil, moisten it with hydrochloric acid, and direct upon it the flame of the blowpipe; if it renders the flame of a rich carmine colour, *strontia* is present.

*c.* If, however, *the presence of magnesia has been* demonstrated, it is necessary that it should be removed from the liquid by some reagent which may not, like *phosphate of soda*, contain an alkali. For this purpose, the reserved portion of the filtrate, after being treated as described in the preceding section (*b.*) is mixed with a saturated solution of *caustic baryta*, which is added as long as a precipitate is produced. After being allowed to stand at rest for a short time, the precipitate, which contains all the magnesia present, is removed by filtration, and *carbonate of ammonia*, and a few drops of *ammonia*, added to the filtrate, and heat applied. The liquid is to be filtered, and placed in a dish, and the ammoniacal salts driven off by evaporation and exposure of the residue to a strong heat; and thus prepared, it may be dissolved in the smallest possible quantity of water, and examined for the alkalies, POTASH and SODA.

### *F. Examination for* POTASH and SODA.

*a.* Add to the solution which contained no MAGNESIA, or from which it has been removed as directed, about three times its bulk of alcohol, support the evaporating dish containing it over the spirit lamp, and boil the mixture, and ignite the alcohol. If a rich *yellow flame* is produced, SODA is present, and the solution may also contain POTASH.

*b.* If the flame is *violet*, SODA is absent, while POTASH is probably present.

*c.* Evaporate the mixture to dryness, and add a little water, so as to dissolve the residue, and divide the solution into two portions:

1. To one portion add *tartaric acid*, and agitate briskly. The formation of a crystalline granular precipitate, shows that potash is present.
2. To the second portion of the solution, concentrated, if necessary, to a small bulk, add an equal

volume of alcohol, some *bichloride of platinum*, and a few drops of *hydrochloric acid*. Agitate, and allow the mixture, if no precipitate appears, to stand at rest for some time. If a yellow crystalline precipitate forms directly, or after some time, POTASH is present. Filter or decant the liquid, in which the *potash salt*, if produced, has been deposited, and place it on a shallow dish (the liquid should contain a sufficient amount of the *platinum* test to render its colour yellow), and allow it to evaporate spontaneously, when, if SODA be also contained in the substance examined, delicate needle-like crystals of a yellow colour will be produced. (*See* 63. VI. *d.*)

59. If after treatment of the substance with the solvents directed (56.), an insoluble residue remains, it may consist, as stated, either of SULPHATE OF LIME, SULPHATE OF BARYTA, SULPHATE OF STRONTIA, INSOLUBLE SILICATES, or CHLORIDES, or of METALLIC SULPHIDES. The presence of compounds of the heavy metals (*mercury*, *silver*, *lead*) may be regarded as certain, if a portion of the insoluble residue, after being moistened with *sulphide of ammonium*, assumes a black colour. The residue must be converted into a soluble form by decomposing it by fusion with an alkaline flux, for which purpose it should be dried and reduced to as fine a powder as possible, and mixed with four times its weight of *carbonate of potash* and *soda* (53.). The mixture should be placed in a little platinum capsule, which may be extemporaneously formed by pressing a piece of platinum foil, about an inch in diameter, over the rounded end of a small pestle, or the handle of a common table-knife, so as to cause it to assume the desired shape. The little cup-shaped vessel thus formed, may be supported on a wire ring, and the flame of the spirit lamp should be directed upon it by means of the blowpipe, so as to heat it to redness, and completely to fuse the mixture. The fused mass should be allowed to cool, and the capsule, with its contents, placed in a beaker, with some water, and heat applied, so as to cause the liquid to boil.

*a.* The solution obtained should be filtered and divided into two portions.

*aa.* One portion should be rendered acid by the addition of an excess of *hydrochloric acid*, or where the substance has been found to contain compounds of the heavy metals (59.) by *nitric acid*, and evaporated to dryness in a porcelain dish, by which the SILICIC ACID (*silica*) which usually separates in flakes on the addition of the acid, will be rendered insoluble. On allowing the dish to cool, and moistening the dry residue with *hydrochloric acid*, or, in the cases indicated above, with *nitric acid*, and adding some water, a solution will be obtained, which, when separated by filtration from the insoluble silica, may be tested for the bases present, as directed in the Systematic Course (58. *A*.).

*bb.* The remaining portion of the solution may be employed for the detection of the acids present, as directed (61.).

*b.* The portion of the fused residue which is not dissolved when boiled with water, should be carefully washed and digested in dilute *nitric* or *hydrochloric acid*, and the solution tested for bases, as directed (58.).

60. For the detection of the alkalies in minerals not decomposed by acids, the following plan must be adopted:

Reduce the mineral to as fine powder as possible, and mix it intimately with four parts of fluor spar, also reduced to fine powder. Place the mixture in a platinum capsule, and add strong sulphuric acid in sufficient quantity to form a thick paste; stir with a piece of platinum wire, and heat gently in a place where there is a current of air, so that the fumes may be quickly carried away. When the mass has become almost dry, and the vapour evolved ceases to produce a gelatinous deposit when received on a piece of glass, moistened with water, apply a stronger heat, so as to drive off the sulphuric acid, and digest the residue with water, and filter. Add to the filtered liquid *chloride of barium*, as long as a precipitate is produced, then *solution of baryta*, until the liquid is rendered alkaline; boil and filter, and add, for the removal of the bayrta, *carbonate of ammonia* and some *ammonia*. Heat gently and filter, and evaporate the liquid to dryness, in a thin porcelain or platinum dish, and heat strongly, so as to drive off all ammoniacal salts. The residue consists of the alkalies (POTASH and SODA) if any were contained in the mineral, and may be dissolved in a small quantity of water, filtered again if necessary, and tested in the usual manner (*Systematic Course*, *F. a.*).

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## METHODS FOR THE DETECTION OF THE ACIDS CONTAINED IN THE SUBSTANCE.

61. The detection of the acids which enter into the composition of soils and manures, or are likely to occur in the compounds examined by the student, can readily be effected by the employment of a few reagents. In the following outline of the methods to be pursued, we shall consider only such acids as are of practical interest.

The acids are divided into two classes, *inorganic* and *organic acids;* the effect of heat being adopted as a means of distinguishing them. All the organic acids, with the exception of *oxalic acid*, being decomposed with separation of charcoal, when exposed to a strong heat, and their compounds with alkalies or alkaline earths being converted into carbonates.

In the examination of the *inorganic acids* the usual course pursued is to use *chloride of barium* and *nitrate of silver* as general or classifying reagents. Thus, by the addition of these reagents to separate portions of the solution of the substance, neutralized, if acid, by the addition of potash, the acids may he divided into three groups, the FIRST GROUP containing *acids which are precipitated from neutral solutions by chloride of barium;* the SECOND GROUP, *acids which are precipitated by nitrate of silver;* and the THIRD GROUP, *acids which are* NOT *precipitated by chloride of barium, nor by nitrate of silver.*

### ARRANGEMENT OF THE INORGANIC ACIDS IN GROUPS.

GROUP I. The members of this group are precipitated by CHLORIDE OF BARIUM from neutral solutions. It contains *arsenious acid, arsenic acid, chromic acid, carbonic acid, silicic acid, sulphuric acid, phosphoric acid, hydrofluoric acid, boracic acid.*

GROUP II. The members of this group are precipitated from neutral solutions, by NITRATE OF SILVER. It contains *hydrochloric acid* (*chlorine*), *hydrobromic acid* (*bromine*), *hydriodic acid* (*iodine*), *hydrocyanic acid* (*prussic acid*), *hydrosulphuric acid* (*sulphuretted hydrogen.*)

GROUP III. The members of this group are not precipitated by either CHLORIDE OF BARIUM or NITRATE OF SILVER. It contains *nitric acid*, *chloric acid.*

The only ORGANIC ACIDS which we shall notice are *oxalic acid* and *acetic acid.*

Having concluded the examination for the bases contained in the substance, the portions of the solutions directed to be reserved (56.) are to be submitted to the various processes required for the detection of the acids which may be present. In the case of substances not wholly soluble in water, the solutions in water and in acids should be separately examined. The acids contained in substances which resist the action of these solvents will be discovered in the course of the systematic examination of the bases, as directed at (59.).

*Note.* The only acids which it is necessary to seek for in the aqueous solution, are those which form soluble compounds with the bases previously discovered (58.).

I. The reaction of the solution (which, if dilute, should be concentrated by evaporation,) on test paper should be examined.

*a.* If it is *neutral*, proceed as directed at (III. *a.*).

*b.* If it is *acid*, ascertain, as directed at (55. VII.), whether the acidity depends upon the presence of a *free* acid, or an acid salt. If a free acid is present, render the liquid neutral by the careful addition of a dilute solution of potash; if no free acid is contained in it, it is to be treated as directed at (III. *a.*).

*c.* If it has an *alkaline* reaction, it probably contains caustic alkalies, alkaline sulphides, or alkaline silicates.

II. Place a portion of the concentrated solution in a test tube (or if the substance is a solid, a portion of the dry powder may with advantage be employed) and add to it an excess of *hydrochloric acid.* An effervescence shows the presence of CARBONIC ACID, or of SULPHURETTED HYDROGEN. If the evolved gas is almost inodorous, it is CARBONIC ACID, and indicates the presence of an alkaline carbonate ; if it has the disagreeable smell of putrid eggs, it is SULPHURETTED HYDROGEN.

> *Confirming Tests.* *a.* Close the test-tube with the thumb, so as to cause the gas to accumulate, and bring it over the mouth of another tube in which some transparent lime water has been placed, and allow the gas to descend into it, taking care to prevent any of the liquid entering with it. If, on agitating the lime water with the gas, a white precipitate or milkiness is produced, CARBONIC ACID is present.
>
> *b.* Moisten a piece of test paper with solution of acetate of lead, and hold it over the mouth of the tube from which the gas is escaping. If a brown or black stain is produced on the paper, SULPHURETTED HYDROGEN (*hydrosulphuric acid*) is present.

If the solution, on the addition of hydrochloric acid, is rendered milky, apply heat, and decant the liquid from the deposit which falls ; collect the precipitate, after washing it by effusion and decantation ; dry it on a piece of thin glass, such as a piece of a Florence flask, which answers admirably in such cases, and heat it over the lamp ; if it melts, and burns, it consists of *sulphur ;* if it remains infusible, it probably consists of *silica,* and may be examined by the *Confirming Test* described at (*b.* III.)

If the presence of carbonic acid, or of sulphuretted hydrogen, has been detected, the solution, filtered if necessary from any separated matters, must be boiled for some time, so as completely to expel the gases, and rendered exactly neutral by the addition of *solution of potash.*

III. *a.* Add to a portion of the *neutral* solution, *chloride of barium.* If no precipitate is produced, none of the members of GROUP I. is present. If a precipitate is formed, add *hydrochloric acid,* so as to render the liquid strongly acid, and heat. If the precipitate does not dissolve, SULPHURIC ACID is present.

*Confirming Test.* Wash the precipitate by agitation with water, allow it to subside in the tube, and decant off the liquid; mix the precipitate in the tube with five or six times its bulk of charcoal in fine powder, and dry the mixture over the water bath. Place a portion of it in a little capsule of platinum foil (59.), and heat it to redness by the blowpipe flame. If the precipitate consists of *sulphate of baryta*, it will be converted into sulphuret of barium; and if the calcined mass is allowed to cool, and placed on a piece of filtering paper, which has been previously moistened by solution of *acetate of lead*, and a drop or two of dilute *hydrochloric acid* be allowed to fall upon it, sulphuretted hydrogen, recognisable by its odour, will be evolved, and a brown or black stain will be produced on the paper. By this method the most minute traces of sulphuric acid can readily be detected.

*b.* Render a portion of the solution distinctly acid by the addition of *hydrochloric acid*, and evaporate to dryness, and heat the residue over the lamp ; allow it to cool, and add to it some dilute hydrochloric acid. If it does not dissolve, it probably consists of SILICIC ACID.

*Confirming Test.* Wash the insoluble residue of (*b.*) with water, and dry it, and mix a portion of it with a little *carbonate of soda*, and add a drop of water, so as to form a stiff paste, which is to be inserted as directed (55.), into a little cavity formed on a piece of charcoal, and exposed for some minutes to the *outer* flame of the blowpipe (*fig.* 5.). If the residue of (*b.*) consists of silica, effervescence from the escape of carbonic acid will be observed, and a clear glass (*silicate of soda*), which remains transparent on cooling, will be produced. The experiment should be repeated, if necessary, with the addition to the substance of a smaller amount of soda, as when too large a quantity of the flux is used, merely an opaque mass is formed.

*c.* To a portion of the original solution of the substance, which, if alkaline, is to be neutralized with nitric acid, add *nitrate of silver*. If a precipitate is formed, members of GROUP II. are present. Add *nitric acid* in excess, and if an insoluble residue remains, which dissolves on the addition of an excess of *ammonia*, and which may be reproduced by adding *nitric acid*, to render the liquid acid, HYDROCHLORIC ACID, or a CHLORINE compound is present.

*d.* Neutralize a portion of the original solution (if acid) by ammonia, and add to it *sulphate of lime*,—if a white precipitate is thrown down, which is insoluble in *acetic acid*, but dissolves in *hydrochloric acid*, OXALIC ACID is present.

*e.* Place a portion of the substance under examination in a test tube, (if it is a fluid, add to it an excess of carbonate of soda and evaporate to dryness,) and add to it some concentrated *sulphuric acid* and a little *alcohol*, and apply heat; if the agreeable odour of acetic ether is evolved, ACETIC ACID is present.

*f.* To a portion of the neutral solution add *ammonia* in excess, then *chloride of ammonium*, and a little *sulphate of magnesia;* agitate strongly,—if a crystalline precipitate forms, PHOSPHORIC ACID is present. (*Confirming Test. See page* 29.)

*g.* Add to a portion of the original liquid about one-third of its bulk of *sulphuric acid;* and when the mixture has become cool, drop into it a crystal of *sulphate of iron.* The production of a brown zone round the crystal shows that NITRIC ACID is present.

*h.* Place a small portion of the substance submitted to examination in a test tube, and add to it some copper filings and sulphuric acid sufficient to cover it, and apply heat. If *orange* fumes appear, and a solution, which, after some time, becomes *blue*, is produced, the presence of NITRIC ACID is demonstrated.

## 62. DETECTION OF THE ACIDS IN COMPOUNDS INSOLUBLE IN WATER, BUT SOLUBLE IN ACIDS.

CARBONIC ACID and SULPHURETTED HYDROGEN (*hydrosulphuric acid*) will, if present, be discovered by the *effervescence* which takes place when the portion of the substance insoluble in water is treated with acids (56. *b.*). The *Confirming Tests* (61., II. *a.* *b.*) will readily enable the student to ascertain the nature of the gases evolved.

*a.* A portion of the acid solution of the substance should be evaporated to dryness, the residue moistened with hydrochloric acid, and water added to it. If a part remains undissolved, it is probably *silicic acid*, and must be examined as directed at (61., III. *b. Confirming Test*).

*b.* Add to a portion of the solution *chloride of barium;* if a precipitate falls, which, when the liquid is largely diluted with water, does not disappear, SULPHURIC ACID is present. (*Confirming Test*, 61., III. *a.*)

*c.* Digest a portion of the substance, if a solid, in *nitric acid;* if yellowish flakes separate in the liquid, and orange fumes are evolved, the substance is a SULPHURET.

*d.* Add to a portion of the solution of the substance in nitric acid, *nitrate of silver;* a white curdy precipitate insoluble in nitric acid, but soluble in ammonia, indicates the presence of HYDROCHLORIC ACID (*a chloride*).

*e.* PHOSPHORIC ACID, if contained in the acid solution of the substance, has already been detected in the examination for the bases. (*Systematic Course*, 58. *C.*)

*f.* OXALIC ACID may be detected by reducing a portion of the original substance to powder, and boiling it with solution of carbonate of soda; or, if the substance is a fluid, adding to it a considerable excess of the carbonate, and boiling the precipitate and fluid for a few minutes. The mixture is to be filtered, and acidified by the addition of *acetic acid*, and solution of sulphate of lime added to it, which, if OXALIC ACID is present, will produce with it a precipitate insoluble in *acetic acid*, but readily soluble in *hydrochloric acid.*

## CHEMICAL EXAMINATION OF WATERS.

63. A quart bottle of the water should be taken from the source and carefully secured by a clean and sound cork, and the examination proceeded with as soon as possible. If upon standing for some time at rest, the water is found to have deposited a sediment (finely divided clay and mineral particles, &c., mechanically suspended in the water), carefully decant off the greater portion of the liquid, and pour the remainder, with the deposited matters, upon a filter.

If considered necessary, the sediment may be treated as directed at (56. *b.*), and examined by the methods described in the Systematic Course (58.).

The examination of the water is to be conducted as follows:

I. Pour some of the water into a glass, and ascertain its smell and taste, and place in it a slip of the neutral test paper. ACID waters will render the paper *red*, ALKALINE waters *blue*. If the water contains SULPHURETTED HYDROGEN, it will give out the odour of rotten eggs; add a few drops of the solution of *acetate of lead;* if a grey or black precipitate falls, it indicates the presence of that gas.

II. Place about a wine-glassful of the water in an ale-glass, and add to it a teaspoonful of *lime water;* a white precipitate shows the presence of CARBONIC ACID; by pouring into the glass an additional quantity of the water, the precipitate will redissolve, but may be made to reappear by adding some more lime water.

III. Evaporate about a wine-glassful of the water to dryness in a porcelain dish over the spirit lamp, and heat the residue *strongly.* If it chars and blackens, it is from ORGANIC matters being present. If when heated it evolves the odour of singed feathers, NITROGENIZED organic matters are contained in it.

IV. Render about a pint of the water acid by the addition of hydrochloric acid, and concentrate it until its bulk is reduced to about half a wine-glassful, by evaporating it over the lamp in a porcelain dish, or in a flask. The concentrated liquid is then to be poured into a porcelain capsule, and evaporated over the water bath nearly to dryness. If upon adding a few drops of caustic potash, or a small portion of milk of lime, to the mixture, the odour of head salts is evolved, and the escaping gas restores the blue colour to a slip of red litmus paper, which should be moistened with water and held over the capsule, the presence of AMMONIA in the water is demonstrated.

V. Introduce a pint of the water into a porcelain dish or Florence flask, and boil until it is reduced to about one-fourth of its volume. Usually a crust collects on its surface, and may consist either of CARBONATE OF LIME, or of

CARBONATE OF MAGNESIA, or of OXIDE OF IRON (dissolved in the water as carbonate of protoxide of iron), or of PHOSPHATE OF LIME, or of all these compounds. The excess of carbonic acid, by which these substances were dissolved, being driven off by the boiling, they are separated in an insoluble form.*

## VI. EXAMINATION OF THE LIQUID FILTERED FROM THE CRUST FORMED ON BOILING THE WATER.

*A*. Filter the concentrated water from the crust, and examine it as follows:—(The insoluble matter is to be set aside, and distilled water poured upon the filter containing it, and also upon the portion of the crust which usually adheres to the interior of the flask, so as to wash away all soluble matters. For its examination, see VIII. *B*.)

*a*. Place about one-half of the liquid in a Florence flask, and examine it by the *test paper*. If the neutral paper be rendered blue, and if on the evaporation of a portion of the liquid to dryness, the residue, on the addition of a drop of muriatic acid, *effervesces*, the water contains fixed alkaline carbonates, CARBONATE OF POTASH, or CARBONATE OF SODA.

*b*. Add to the filtered liquid about a teaspoonful of solution of *chloride of ammonium*, a few drops of *liquid ammonia*, and *solution of carbonate of ammonia* as long as any precipitate falls, and heat over the spirit lamp; a white precipitate indicates *lime* present in the water, in the form of SULPHATE OF LIME.

*c*. Filter from the lime precipitate, and to one-fourth part of the clear liquid add solution of *phosphate of soda*; agitate violently, and set the tube aside for some hours. The formation of a white crystalline precipitate indicates the presence of MAGNESIA.

*d*. Pour into a porcelain dish the remaining three-fourths of the liquid from which the lime has been separated by carbonate of ammonia, as directed at (*b*.) and evaporate to dryness, and heat over the lamp until fumes cease to be given off. If a residue soluble in water is left, it may consist of the alkalies (*potash* and *soda*). Dissolve the residue in a little water, and render acid by the addition of hydrochloric acid, and evaporate to dryness in a porcelain capsule, and heat strongly. Add water to the residue; if a portion of it remains undissolved it is SILICA. (*Confirm as directed at* 61., III. *b.*)

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* If the water contains much sulphate of lime (*gypsum*), which is *sparingly* soluble in water, a portion of that substance may be separated by the concentration of the water, and will be found in the crust.

Place a portion of the solution obtained, in a teaspoon, and add to it double the quantity of *alcohol;* heat over the lamp and ignite the alcohol, when if SODA is present, the flame will be rendered of a golden-yellow colour.* To the remainder of the solution add an equal volume of spirits of wine and a few drops of hydrochloric acid, and a sufficient quantity of solution of *chloride of platinum* to render the liquid yellow. Agitate the mixture and allow it to remain for some time at rest. If a yellow crystalline precipitate forms, it shows the presence of POTASH. If no precipitate is produced, even after the mixture has been allowed to stand for some time, the *soluble* saline residue of (*d.*) consisted solely of SODA.

VII. The remaining portion of the liquid filtered from the crust formed by boiling the original water (*see* VI.) is divided into four parts, and placed in test tubes.

To No. 1, add a few drops of solution of *nitrate of silver*, and a drop or two of *nitric acid;* a precipitate indicates the presence of *chlorine*, probably present in CHLORIDE OF SODIUM—common salt.

To No. 2, add a few drops of solution of *chloride of barium* and a drop of *muriatic acid;* a precipitate shows SULPHURIC ACID.

To No. 3, add a few drops of *acetic acid* and a drop of solution of *perchloride of iron*, and allow the tube to remain at rest for some hours; the formation of a yellowish-white precipitate shows the presence of PHOSPHORIC ACID.

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* The presence of very minute quantities of soda is, however, with greater certainty detected by the intensely yellow colour which its salts communicate to the blowpipe flame, or, as has been shown by Dr. Andrews, by the brilliant display of colours presented by its platinum compound when acted on by polarized light.

To No. 4, add about an equal volume of *sulphuric acid*, and allow the mixture to become cold, drop into it a crystal of *protosulphate of iron;* a brown halo forming round the crystal indicates the presence of NITRIC ACID.

## VIII. EXAMINATION OF THE CRUST FORMED ON BOILING THE ORIGINAL WATER.

*B.* Take dilute muriatic acid (1 part acid and 6 water) and pour a portion of it upon the matter on the filter preserved for examination, the funnel containing the filter being supported over a tube or glass beaker (*see fig.* 3.), and also add some of the acid to the flask in which the water has been boiled, to dissolve the portion of the crust which usually adheres to it. An effervescence shows the presence of CARBONIC ACID.

*a.* Place the solution in a dish, add to it a drop or two of nitric acid, and evaporate to dryness. Pour some dilute muriatic acid on the residue. If a portion remains insoluble, it consists of SILICA.

*b.* Filter the liquid, if necessary, from the insoluble silica, and divide it into three parts :

*aa.* To No. 1, add *ammonia,* so as to render it alkaline. Ascertain the alkalinity by means of litmus paper. The production of a brownish precipitate on the addition of the ammonia, shows that the crust contains IRON.

*Confirming Test.* Filter the liquid, and dissolve the precipitate collected, by pouring a few drops of muriatic acid on the paper, receiving the solution in a test tube ; and add to it a drop of solution of *ferrocyanide* of *potassium,* which, if iron be present, will render the liquid of a rich blue colour.

*bb.* Examine the filtrate from the precipitate produced by ammonia, for the presence of LIME—in the state of *carbonate,* and also of *sulphate,* if the solution of the crust is found (*c.* No. 2.) to contain sulphuric acid—by the addition of solution of *carbonate of ammonia;* and for MAGNESIA—in the state of carbonate—by the addition to the liquid filtered from the precipitate produced by carbonate of ammonia, of *phosphate of soda*, and a few drops of ammonia, in the manner directed for the investigation of the substances held in solution in the liquid filtered from the crust formed on boiling the water (*see* VI. *b.*).

*c.* To No. 2. add some solution of *chloride of barium*, agitate, and allow the liquid to remain for some hours; if a precipitate forms, the crust contained SULPHURIC ACID. (*Confirming Test*, 61. III. *a.*)

*d.* To No. 3. add *carbonate of soda* until the liquid is only faintly acid, then *acetate of soda* in excess, and a drop of solution of *perchloride of iron;* allow the mixture to remain at rest for twelve hours, when, if a white precipitate has collected, PHOSPHORIC ACID is present. Usually the presence of that acid cannot be detected except when a large quantity of the water is submitted to examination. By the employment, however, of *molybdate of ammonia*, (*see Systematic Course*, *page* 29, *Note*), the most minute traces of it may be discovered.

## IX. HARDNESS OF WATERS.

For many practical purposes, as for bleaching, steeping flax, &c., it will be sufficient to ascertain the *hardness* of waters, which is in proportion to the amount of the compounds of lime, iron, and magnesia, which they hold in solution. The degree of hardness possessed by a sample of water is most conveniently examined by the employment of a standard solution of soap in alcohol, a few drops of which, when agitated with distilled water, at once produces a persistent lather, while the lather which the same quantity of the solution forms with ordinary spring water is quickly broken up, the soap being decomposed and curdled by the lime, &c., contained in the water. The soap solution is usually sold of the strength that 32 measures of it violently agitated in a stoppered bottle with 100 measures of the water, produce a lather, which, when the bottle is placed on its side, will remain unbroken on the surface of the liquid *for five minutes* with a water in which the hardness is equal to that which would be produced by 16 grains of carbonate of lime (chalk) per gallon, dissolved in the water, in the form of bicarbonate of lime, or by a quantity of a soluble salt of iron, or magnesia equivalent to 16 grains of chalk.

*Preparation of the Soap Test.* The soap solution which is employed is prepared by dissolving about 120 grains of white soap in a pint of proof spirits. Its graduation is effected by means of a standard solution of chloride of calcium, which is obtained by dissolving 16 grains of white marble or calcareous spar (pure carbonate of lime) in dilute hydrochloric acid. The marble should be placed in a deep beaker, and the acid added to it in small quantities at a time, so as to avoid loss from too brisk effervescence. The solution should be evaporated to dryness, and exposed for a considerable time to the heat, so as to drive off all excess of acid; then dissolved in a little water, and if on examination by blue litmus paper, it is found not to be neutral, again evaporated to dryness, and re-dissolved in water. When a neutral solution has been obtained, distilled water is to be added to it, so as exactly to make up a gallon. Thus prepared, the solution of chloride of calcium represents a water of 16 degrees of hardness, and will serve for the graduation of the "soap test," which is to be examined by introducing 100 measures of it into a stoppered bottle, and carefully adding to it from a graduated tube the soap solution, (the tubes described under the head of ALKALIMETRY will serve to measure both the soap test and the standard solution,) agitating the bottle after each addition of the test, until the lather which is formed remains unbroken, when the bottle is placed on its side on the table, over the entire surface of the liquid *for five minutes.* The number of measures of the soap test poured out is then to be observed, and if more or less than 32 measures has been required to produce a persistent lather, either soap or spirit is to be added as necessary, until exactly 32 measures of the test are found to produce a lather which continues unbroken *for five minutes,* with the 100 measures of the standard solution. The method of employing the soap test for the examination of natural waters, is precisely similar to that required to ascertain its strength, as above-described. 100 measures of the water to be examined are introduced into a stoppered bottle, capable of containing twice that quantity of liquid, and briskly agitated, so as to disengage the free carbonic acid, which has the property of breaking up the lather formed upon the addition of the soap test. By sucking out the air from the upper part of the bottle, by means of a glass tube, and repeating the agitation and exhaustion of the air two or three times, all risk of error will be removed. The soap test is then to be added in small quantities, from the measured tube, and the amount consumed in producing a presistent lather noted, and in about half-an-hour the bottle should be again shaken, and if the lather breaks up in less than five minutes, some more of the test should be added; and the total amount required, by reference to the following table, calculated by Professor Clarke, of Aberdeen, to whom we are indebted for this excellent method of testing the qualities of waters, will enable us correctly to estimate the hardness of the water :—

*Table of the Soap Test Measures, corresponding to* 100 *Test Measures of each Standard Solution.*

| Degree of Hardness. | | Soap Test Measures. | Differences for the next 1° of Hardness. |
|---|---|---|---|
| 0 | (Distilled Water) | 1·4 | 1·8 |
| 1 | | 3·2 | 2·2 |
| 2 | | 5·4 | 2·2 |
| 3 | | 7·6 | 2·0 |
| 4 | | 9·6 | 2·0 |
| 5 | | 11·6 | 2·0 |
| 6 | | 13·6 | 2·0 |
| 7 | | 15·6 | 1·9 |
| 8 | | 17·5 | 1·9 |
| 9 | | 19·4 | 1·9 |
| 10 | | 21·3 | 1·8 |
| 11 | | 23·1 | 1·8 |
| 12 | | 24·9 | 1·8 |
| 13 | | 26·7 | 1·8 |
| 14 | | 28·5 | 1·8 |
| 15 | | 30·3 | 1·7 |
| 16 | | 32·0 | |

When the measures of soap test necessary to form a lather with 100 test measures of a water, exactly correspond with a standard solution, then the degree of hardness will be the corresponding integral number found in the first column. Thus 24·9 of soap test will indicate 12° of hardness; 26·7 of soap test will indicate 13° of hardness.

But if the measures of soap test do not exactly correspond with a number in the first column, the hardness will be expressed partly by an integer, and partly by a fraction.

The *integer* will be the hardness corresponding to the next lower number in the soap test column.

The *numerator* of the fraction will be the excess of the soap test measures in question above this number. The *denominator* of the fraction will be the corresponding difference, which follows the soap test in the next column.

*Example.*—Let 25·8 be the measures of soap test required by 100 test measures of a given water.

24·9 is the next lower number in the soap test column. Therefore 12° of hardness, the corresponding degree, is *the integral part* of the required hardness.

The numerator of the fraction of 25·8—24·9=·9. The denominator is the corresponding difference=1.8. *The fraction* itself is $\frac{\cdot 9}{1\cdot 8}=\cdot 5$.

The whole hardness, therefore, is 12·5 degress.

In cases where very hard waters do not afford a permanent lather with 32 test measures of the soap test, the following is the method directed to be pursued :—

Add 100 measures of distilled water to the mixture in the bottle, and continue to drop into it soap test as before, until in all 60 measures have been added, if enough has not been previously added to produce a lather. If at 60 measures of soap test, or at any number of measures between 32 and 60, the proper lather be produced, then the final trial is to be made in the following manner :—100 test measures of the water under trial, is to be mixed with 100 measures of distilled water; to this mixture soap test is to be added until a lather is produced. The number of measures of soap test is to be divided by 2, and the result will be less than 32, and accordingly may be expressed in a degree of hardness. The double of such degree will be the hardness of the water under trial. For instance, if half the soap test which has been required corresponds to $10\frac{5}{10}$ degrees of hardness, then the hardness under trial will be 21. If, however the addition of 100 measures of distilled water to 100 measures of water to be tested, do not form a solution which is capable of producing a lather with 60 test measures of soap test, then 100 measures more of distilled water added, and the resulting number of measures of soap test divided by 3 to arrive at the degree of hardness of the mixture, and that multiplied by 3, gives the hardness of the water under examination, and so on.

In the greater number of cases the calcareous and other impurities which render natural waters "hard," exist in the form of carbonates held in solution by an excess of carbonic acid, so that when such waters are boiled for some time, the volatile acid (2.) is driven off, and the carbonates are separated in an insoluble form, causing the water to become turbid, and gradually to deposit a crust which adheres to the inside of our kettles, and coats the pipes and boilers of steam-engines, and is frequently productive, not merely of considerable annoyance in manufactories, but also of serious accidents.

Waters which owe their hardness to the presence of the compounds mentioned, may be softened and rendered better adapted for domestic use by protracted boiling, and even by lengthened exposure to the air in open basins. It is, therefore, of interest in the examination of a water, to ascertain not only the degree of hardness which it exhibits when freshly drawn, but also that which it is found to possess after being boiled. For this purpose it is necessary that a measured quantity of the water should be boiled at least 2½ hours, so as to effectually decompose the bicarbonates; taking care by adding distilled water from time to time during the boiling, to supply the loss of liquid by evaporation (so as to prevent the separation of sulphate of lime). At the conclusion of the boiling, the water, when cooled, should be filtered, and the original quantity having been exactly made up by the addition of distilled water, its hardness may be determined by the methods already described.

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## QUALITATIVE ANALYSIS OF SOILS AND MANURES.

64. After the student has acquired some experience in the performance of the operations required for the detection of the bases and acids included in the Systematic Course of investigation, he will be prepared to apply the information which he has obtained to the examination of soils and manures. In the qualitative analysis, both of soils and of the natural and artificial compounds which are employed to

increase or restore their productiveness, it is essential that separate examinations should be made to discover—

1. The materials which they contain in a form capable of being dissolved by water.
2. The substances insoluble, or only partially soluble in water, but soluble in dilute acids.
3. The materials insoluble both in water and acids.

Plants cannot take up from the soil the inorganic matters necessary for their support, except when presented to them dissolved in water. The estimation, therefore, of the amount and kind of substances soluble in water, which a specimen of soil contains, is of great importance in studying its qualities, and must not be overlooked, as it shews us the store of nutritious ingredients, in an *immediately available* form, which it can afford. By subsequently acting on the specimen with *hydrochloric acid*, a solution is obtained, in which we discover the kind and quantity of ingredients which, by the influence of cultivation, and of the decomposing action of the atmospheric agents, oxygen, carbonic acid, water, &c., are capable of being gradually brought into a soluble available condition. The examination of *the portion insoluble in acids* is also calculated to afford us useful information, and by its qualitative analysis, and especially by the application of the methods given for the identification of the mineral remains which compose it (*See Preliminary Examination, page* 14), we may judge of the amount and value of the "inactive capital" which the soil contains, and of the nature of the constituents which are stored up in an insoluble dormant condition.

To ascertain the kind of matters contained in a specimen of soil, the student may proceed as follows :—

I. A portion of the soil (about 4 oz.) should be boiled in a flask with half a pint of distilled water, for half an hour, and the solution having been allowed to remain at rest for some time, the supernatant liquid should be decanted, and some more water placed upon the insoluble matters in the flask, and the mixture again boiled, and the solution separated by decantation. As the finely divided matters of heavy clay soils subside very slowly, it may be requisite in some cases, after decanting the solutions, to permit them to remain at rest for at least twenty-four hours, and again to pour off the clear liquid, and to filter it through a double filter.* The liquid, when completely free from all mechanically suspended matter, should be placed in a porcelain dish, and evaporated until its volume is reduced to about four ounces. The concentrated solution is to be divided into two parts, and one portion examined for the bases, and the other for the acids present, by the processes given for the detection of the substances contained in waters, at (63.).

II. A portion (about 500 grains) of the soil which has been boiled with water is to be placed in a filter and washed repeatedly with hot water, until a few drops of the filtrate, evaporated on a piece of glass, leave merely a trace of residue. The wash water may be thrown away. The washed portion of soil may then be placed in a flask, with about two ounces of dilute hydrochloric acid, and digested over the lamp for an hour, and the solution diluted with three or four times its bulk of water, heated to boiling, and filtered. If, on the addition of hydrochloric acid to the soil, an *effervescence* is produced, it indicates the presence of CARBONIC ACID. The filtrate is to be examined for bases and acids, by the methods described in the Systematic Course (58 *commencing at B.*); two-thirds of the solution being employed for the detection of the bases.

III. The portion of the soil insoluble in hydrochloric acid should be washed with water until the liquid ceases to exhibit an acid reaction on litmus paper. The matters composing the residue should be examined with a magnifying glass, and, by submitting them to the physical and chemical processes described at (55. *Preliminary Examination*), their nature may be ascertained. The composition of the insoluble matter of the soil, and the kind of materials which it contains in an inactive condition, may also be ascertained by the methods given for the examination of compounds insoluble in acids at (59.).

IV. A portion of the original soil should be placed in a dish, with some *milk of lime*, or solution of *potash*, and examined for AMMONIA. (*See. Preliminary Examination, Operation VI.*)

An examination of the results of the analysis, given in the *Appendix*, will show the student the usual composition of cultivated soils.

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* Made by forming two filters, as directed at (16.), and placing one within the other.

## ANALYSIS

### OF DISSOLVED (*vitriolized*) BONES, SUPERPHOSPHATES, AND AMMONIACAL MANURES.

65. These manures may be expected to contain several, or all, of the following substances :—

Phosphate of lime (insoluble in water).
Biphosphate of lime (soluble in water).
Phosphate of magnesia.
Sulphate of lime.
Organic matters.
Ammoniacal salts.
Chlorides of sodium and potassium.
Alkaline sulphates, phosphates, and nitrates.
Carbonate of lime.
Clay and sand.
Water.

Their examination may be conducted as follows :—

I. Dry 100 grains of the manure, taken from the sample, previously rubbed to powder in a mortar. The loss is WATER. Employ a water-bath to dry the substance, as directed at page 8 (19.).

II. Place the residue of (I.) in a porcelain crucible; support the crucible by the wire support (*fig.* 1.) and expose it to the heat of the lamp, until the black colour which it usually assumes has entirely disappeared. If the manure, when heated, produces a crackling noise (*decrepitates*), common salt is probably contained in it, and will be discovered on the examination of the solution in water (III.). The loss of weight which the substance experiences when incinerated, will represent the ORGANIC AND AMMONIACAL MATTERS present.

III. Digest the residue of (II.) in water, filter, and wash the undissolved matters with water to which some alcohol has been added, and, when washed, place it in a crucible and expose to the heat of the lamp, and ascertain the weight of the insoluble matter. Subtract the weight found from the weight of the residue of (II.) operated upon: the difference will represent the amount of ALKALINE SALTS, &c., soluble in water. Evaporate the filtrate to about two ounces, and divide into two separate portions, and examine one portion for bases by the methods described at (63. VI. *a.*), and the second portion for the acids present, as directed at (63. VII.), with the exception of *nitric acid*, which, if present, would be removed by the ignition of the sample. For the detection of that acid, a portion of the specimen is to be boiled with water, and the solution filtered and evaporated to a small bulk, and tested, as directed at (63. VII. No. 4.).

IV. Place the weighed residue of (III.) in a flask, with some dilute hydrochloric acid (about one ouuce of which will be sufficient), and boil for a quarter of an hour. Observe whether an effervescence indicating the presence of *carbonic acid* takes place on the addition of the acid (*See Note, p.* 17.). Pour the undissolved matter upon a filter, and wash with a little water, dry, and ascertain its weight, which will represent the amount of SAND, GYPSUM (*sulphate of lime*), and EARTHY MATTERS contained in the manure.

To ascertain the substances which have been dissolved by the acid.

*a.* Add to the acid filtrate a slight excess of AMMONIA; cover the beaker with a plate of glass, so as to prevent the access of air, and when the precipitate which forms has subsided, pour the clear liquid upon a filter, so as to filter it as rapidly as possible, and then wash out the precipitate with water, and place it upon the filter; wash it with more water, and after drying it over the water-bath, remove it as completely as possible from the filter and introduce it into a crucible, and apply a strong heat, and ascertain its weight, which will represent the amount of PHOSPHATES OF LIME and MAGNESIA present.

*b.* To the filtrate from (*a.*) add oxalate of ammonia as long as a precipitate falls. Heat the mixture, and collect the precipitate upon a filter; wash it with water, and dry over the water-bath, and then introduce it into a porcelain crucible, supported over the spirit-lamp; apply at first a gentle heat, and then heat strongly, until all traces of charcoal left by the filter are burned away. Weigh the powder, which will consist of CARBONATE OF LIME, every 100 grains of which represent 44 grains of LIME.*

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* Or 136 parts of burned gypsum, or 172 parts of common gypsum.

V. In the examination of guano it is unnecessary to ascertain the composition of the insoluble residue of (IV.); but if required, as in the case of vitriolized bones and other artificial manures, the amount of *sulphate of lime* present may be determined as follows:—Introduce the residue into a flask, and boil for half-an-hour in three or four ounces of a strong solution of *carbonate of soda.* Place the undissolved residue upon a filter; after washing it, ignite it in a crucible, and weigh. Having ascertained its weight, place it in a beaker with some dilute hydrochloric acid. If it *entirely dissolves, with effervescence,* it may be regarded as wholly composed of *carbonate of lime,* produced by the combination of the *carbonic acid* of the *carbonate of soda* with lime contained in the manure, in the form of *gypsum,* which may have been formed in the process of manufacture—as in the preparation of dissolved bones—or added. If the solid matter which remains after boiling the residue of (IV.) with carbonate of soda *does not wholly dissolve* in dilute *hydrochloric acid,* pour the contents of the beaker upon a filter, and wash the undissolved matters until the liquid which passes through the filter ceases to redden blue litmus paper; then dry the residue and ignite it in a crucible, and ascertain its weight, which will be the amount of SAND and CLAY contained in the sample. By deducting the weight of these ingredients from that of the residue of (IV.) insoluble in dilute hydrochloric acid, the difference will represent the amount of GYPSUM* contained in the manure.

VI. *Determination of the Ammonia.* The amount of ammonia in ammoniacal manures, and also that which a specimen of guano may be expected to yield by the decomposition of the nitrogenized compounds contained in it, may be estimated with sufficient accuracy for practical purposes, by the following method:—Introduce 100 grains of the specimen into a stoppered glass retort, and adapt the neck of the retort to a glass receiver, in which about four ounces of dilute hydrochloric acid† have been placed. Next introduce into the retort about 200 grains of quick lime and three ounces of water. Apply the heat of the lamp to the retort (which, to secure the uniform distribution of the heat, should be supported on a piece of sheet iron or wire gauze, placed under it on the ring of the stand) until all the water has distilled over into the receiver. Pour the contents of the receiver into a porcelain dish, supported on the water-bath, and evaporate to dryness. When completely dry, place the dish on the balance and counterpoise it. This done, support it on a ring over the lamp, and heat strongly so long as vapours continue to be given off, and when it is cool replace it on the balance, and add weights to restore the equilibrium. The number of grains required will represent the weight of the compound of ammonia produced by the union of the ammonia of the manure with the hydrochloric acid in the receiver. Every 100 grains of this compound (*muriate of ammonia*) obtained, indicate $31\frac{8}{10}$ grains of AMMONIA in the manure.* Suppose, therefore, that in an experiment conducted as directed, the muriate of ammonia has been found to amount to $7\frac{1}{2}$ grains, the following rule will give the quantity of ammonia :—

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* That is, of *burned* gypsum, 68 parts of which represent 86 parts of common (*hydrated*) gypsum.

† One part of concentrated acid diluted with two parts of water.

$$100 : 31{\cdot}8 :: 7{\cdot}5 = 2{\cdot}37.$$

VII. *Determination of the Amount of Soluble Phosphates.* As the agricultural value of vitriolized bone manure (dissolved bones) mainly depends upon the amount of *phosphate of lime in a soluble form* which it contains, it is essential in its examination that the proportion of that ingredient should be determined. The most simple plan for this purpose is as follows :—

*a.* Boil 300 grains of the manure with half a pint of water, proceeding as directed at (64. I.) The entire quantity of the filtrate should be mixed with *ammonia* and the *phosphates of lime* and *magnesia*, estimated as directed at (65. IV., *a.*).

*b.* To the filtrate from (*a.*), *ammoniacal sulphate of magnesia*, (formed by adding to solution of *sulphate of magnesia* a slight excess of *ammonia*, and then a sufficient amount of *chloride of ammonium* to cause the precipitate which the ammonia produces to disappear,) is to be added so long as it causes a precipitate to fall. The mixture is to be well shaken, and allowed to remain at rest for twelve hours. The precipitate is then collected on a filter and washed with water, with which a fifth part of ammonia has been mixed, dried on the water-bath, and exposed for a considerable time to a strong heat in a crucible. The greyish white mass which remains will consist of a compound of phosphoric acid and magnesia (*pyrophosphate of magnesia*), every 100 grains of which indicate 64 grains of phosphoric acid = 132 grains of phosphate of lime. By adding together the weights of the phosphates obtained in (*a.* and *b.*) the sum divided by 3 will represent the amount of PHOSPHATES, which, for practical purposes, are usually considered as PHOSPHATE OF LIME, which exists in the manure *in a soluble form;* and by subtracting the weight of these from that of the *phosphates* already determined, as directed at (65. IV. *a.*), the amount of phosphate of lime in an insoluble condition in the specimen may be ascertained.

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* See the Table of Equivalents in the *Appendix*.

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## VALUATION

### OF GUANO AND ARTIFICIAL MANURES.

66. The actual value of a sample of guano can be ascertained only by its accurate chemical analysis, and depends, as the farmer is now aware, thanks to the attention which has been directed to the subject by the researches of the chemist, upon the proportion of the ingredients of plants which it is capable of supplying. Of these, "*the organic* and *ammoniacal matters,*" which yield *ammonia*, and the "*phosphates of lime* and *magnesia*, usually termed "earthy phosphates," are clearly the most important. In estimating, therefore, the qualities of a specimen of guano, the proportions of these two classes of its constituents should chiefly occupy attention; and it should, in every case, be examined what amount of *ammonia* "the organic and ammoniacal compound" are capable of affording by their decomposition. The amount of "*alkaline salts*" in the sample is of comparatively trifling importance. A good many years ago, in conjunction with our friend Dr. Ritchie, the Secretary of the Chemico-Agricultural Society, we calculated the money value of the several constituents of the substances employed as manures in this country, and adopted the prices fixed upon, in our Laboratory calculations. This method is now generally followed by Chemists, and has been employed with much advantage to the interests of the farmer.

By its application we can obtain, at least, a close approximation to the actual money value of guano and the various compound manures offered for sale. The method which we originally adopted was, to calculate the value per pound weight of the fertilising ingredients contained in 100 pounds of the manure, and afterwards in 2,240 pounds, or one ton. The calculation, however, may be much shortened by a plan suggested by Mr. Nesbit, of London, which consists in regarding the components of the manure as given in the analysis to represent 100 tons; and by multiplying each ingredient by its recognised price per ton, and adding up the product obtained, and dividing the sum by one hundred, we readily obtain the actual value per ton of the manure. This modification of the method will at once enable the farmer, when presented with an analysis by the merchant, to judge whether the article which it represents is worth the price demanded for it, and will render it impossible for manufacturers of guano to succeed, by giving a list of chemical substances in their statements, in imposing upon dealers, who have merely to bear in mind what has been stated—that unless the manures which they are invited to patronize are shown by analysis to contain fair value, in the shape of ammonia and phosphates, they should be rejected. The substances in guano and the various artificial manures which are prepared for farmers, derive, as we have said, their chief value from the amount of *ammonia* and of *phosphates* which they are capable of yielding for the nourishment of plants. The other ingredients which exist in them, though they possess a certain value, are of low price, and from the trifling proportion of them which a useful manure or good guano should contain, may be safely omitted in our calculations. But the now-admitted importance of the condition in which the phosphates are supplied to our crops, renders it essential that in our examinations of manures, we should carefully ascertain what proportion of these compounds exist in them in a soluble—immediately available—form. The manufacturer of vitriolized bones endeavours to render the phosphates soluble by acting on them with sulphuric acid, and his skill is shown by the amount of the soluble compound which his manure affords. In guano also there is usually a small amount of soluble phosphates, the phosphoric acid existing in combination with the alkalies present, forming a compound soluble in water. The existence of soluble phosphates in guano has long been known, but it is only since the increased value attached to the application of the phosphates in this form, that it has been thought necessary to specify their amount separately.

With respect to the valuation of guano and artificial manures, the average prices which we have adopted as indicating the actual value of their respective constituents have been calculated with reference to the cost at which these substances could be purchased by the farmer in the various commercial compounds to be found in the market, selecting, of course, those compounds which will yield them at the cheapest rate.

The following are the prices per ton at which the chief ingredients of manure in a state of purity may be estimated. These prices, it must be recollected, will be influenced by the fluctuations in the rates to which to which the compounds upon which the calculations of their value is based are subject. They, however, may readily be corrected, and will enable farmers to obtain a close approximation to the money value of manures:—

VALUE PER TON OF THE INGREDIENTS SHOWN BY ANALYSIS TO EXIST IN GUANO AND ARTIFICAL MANURES.

| | | | |
|---|---|---|---|
| Water, ... ... ... ... ... | £0 | 0 | 0 |
| Organic and ammoniacal nitrogenized matters, ... ... ... | Dependent upon the amount of ammonia which they are capable of yielding. | | |
| Organic matters destitute of nitrogen, and not capable of yielding ammonia by their decay, ... ... ... ... ... | £0 | 10 | 0 |
| Ammonia,... ... ... ... ... | 56 | 0 | 0 |
| Phosphate of lime, ... ... ... | 7 | 0 | 0 |
| Phosphate of lime rendered soluble, ... | 25 | 0 | 0 |
| Alkaline salts, when chiefly soda compounds | 1 | 0 | 0 |
| Potash, ... ... ... ... ... | 20 | 0 | 0 |
| Common sulphate of lime, gypsum unburnt, | 1 | 0 | 0 |

The above prices, which have been carefully calculated from consideration of the rates at which the various fertilizing ingredients mentioned can at present be obtained by farmers in this country, will afford the purchaser of manures the means of judging how far the substances which a manure is shown by analysis to contain, are worth the price demanded for it.

ILLUSTRATION OF THE METHOD OF VALUATION DESCRIBED.

A compound lately exposed for sale in the North of Ireland, and described as a Peruvian guano of superior quality, was found, on examination, to consist of the following ingredients:—

| | |
|---|---|
| Water, ... ... ... ... ... | 9·84 |
| Organic matter and ammoniacal salts, ... | 22·16* |
| Alkaline sulphates and chlorides, ... | 3·05 |
| Phosphates of lime and magnesia, ... | 16·08 |
| Carbonate of lime, ... ... ... | 9·23 |
| Earthy matters, ... ... ... | 39·64 |
| | 100·00 |

* Capable of yielding 3·5 parts of Ammonia.

The valuation of the sample, according to the plan described, will show how far it falls below genuine Peruvian guano, worth from £11 to £12 per ton:—

| | | | VALUE PER TON. | | | TOTAL. | |
|---|---|---|---|---|---|---|---|
| Moisture, ... ... | 9·84 | × | £0 | 0 | | £0 | 0 |
| Organic matters, ... | 22·16 | × | 0 | 10 | = | 11 | 0 |
| Alkaline sulphates and chlorides,... ... | 3·05 | × | 1 | 0 | = | 13 | 0 |
| Phosphates of lime and magnesia, .. | 16·08 | × | 7 | 0 | = | 112 | 0 |
| Carbonate of lime, ... | 9·23 | × | 0 | 0 | | 0 | 0 |
| Earthy matters, (red loam), ... ... | 39·64 | × | 0 | 0 | | 0 | 0 |
| Ammonia, ... ... | 3·5 | × | 56 | 0 | = | 196 | 0 |
| | | | | | | 1·00)3,22 | 0 |
| | | | | | | 20 | |
| | | | | | | 4·40* | |

---

* To assimilate the prices given in the table with the present (1858) increased value of bones, guano, and all fertilizing materials, it will be necessary to add one-sixth to the value per ton of the manure.

Thus taking the proportions of the several constituents, shown by analysis to be contained in the manure, to represent tons, we have, in 100 tons, ingredients which, to the farmer are worth £322, so that the actual value of the manure is only £3 4s. per ton.

## 67. HOW FARMERS MAY DETECT THE ADULTERATION OF GUANO.

As it may occasionally be useful that farmers should be enabled to test the qualities of guano, the following simple plan of proceeding, in the absence of facilities for a more extended chemical analysis, may be adopted :—

1. Weigh 50 grains of the sample, and dry it completely by placing it in a paper before the fire, or over the water bath. The loss of weight which is produced by drying the sample, multiplied by 2, will represent the amount of *water* present in 100 grains ; of course, the less water present the better the sample.

2. Weigh 20 grains of the dried sample, and spread it upon a piece of thin glass, the size of a half-crown, broken from the bottom of a Florence oil flask, and support the glass by means of a wire ring and candlestick (*fig.* 1.), over the flame of a spirit-lamp, or when a spirit-lamp cannot be obtained, place the guano in a metal spoon, and expose it to the heat of a clear fire. Heat the specimen either over the lamp or fire until the blackness which is at first produced by the charred organic matter has entirely disappeared. If the residue, after being strongly heated for half-an-hour, is greyish *white*, the guano is probably genuine ; if it assumes a *reddish* colour, it has been mixed with earthy matters. Ascertain the loss of weight, which, multiplied by 5, will, after subtracting the amount of water found, by operation No. 1, to be contained in 100 parts of the guano, represent the per-centage of *organic* and *ammoniacal matters.*

3. Place a teaspoonful of the guano in a bottle ; add to it about a tablespoonful of quick lime made into a cream with water ; shake the mixture, and observe the intensity of the ammoniacal odour. *The stronger the smell of head salts produced, the better the guano.*

4. Introduce the matter which is left on burning the sample of guano *(operation 2)* into a tumbler, and add to it a teaspoonful of spirits of salts, and about half a glass of water. If a brisk escape of gas, shown by the bubbling up of the liquor, is observed, the guano is adulterated (by limestone, chalk, or marly earth). Allow the mixture to remain for half an hour, agitating it occasionally, and then pour it upon a filter formed from a piece of blotting paper, or decant off the clear liquid portion, and wash it from the acid by pouring water over it two or three times. Dry the solid residue thoroughly before the fire or on the water bath, and ascertain its weight, which, multiplied by 5, will represent the *sand and earthy matters* contained in the sample.

By means of these simple operations, which any person of ordinary intelligence may successfully perform, the character of a sample of guano can readily be discovered. If the purchaser has reason to conclude that the manure sold to him as genuine, be adulterated, he should at once forward a sample of it to a chemist, that its actual value may be ascertained. For this purpose about two ounces of the guano will be sufficient, which may be enclosed in a double covering of stout paper, and forwarded by post.

The following statement of the composition of a sample of excellent guano lately sold in Belfast, will show the farmer the proportions in which the several ingredients of that manure, when genuine, are usually present, and serve as a standard of comparison in his examinations of the composition of samples by the methods described :—

100 parts consisted of—

| | |
|---|---|
| Water ... ... ... ... | 9·24 |
| Organic and ammoniacal matters ... | 53·76* |
| Phosphates of lime and magnesia ... | 26·12 |
| Alkaline salts ... ... ... | 8·73 |
| Sand and earthy matters ... ... | 2·15 |
| | 100·00 |

* Capable of yielding AMMONIA, 16·48.

# ALKALIMETRY.

## EXAMINATION OF SODA ASH, BARILLA, CARBONATE OF POTASH, &c.

68. In many cases, especially in the examination of substances employed in the arts, and in manufactures, the commercial or industrial value of which, as is frequently the case, depends upon the amount of one of the ingredients which they contain, processess are adopted by which the proportion of the valuable ingredient can be expeditiously determined. Thus, the value of a sample of soda ash, which is an impure carbonate of soda, depends upon the per-centage of alkali which it is capable of affording, and to enable the manufacturer and the bleacher rapidly to estimate its amount, a method is employed which, by the use of graduated test solutions, as in the process described for the determination of the "hardness" of waters, accurately affords the desired information.

The methods employed in alkalimetry, as the processes which have for their object the *quantitative* estimation of alkalies are termed, are based upon the law of chemical combination, that when a known quantity of acid is neutralised by an alkali, the amount of alkali which combines with the acid to form a neutral salt, is definite and uniform. Thus, if 49 parts by weight of oil of vitriol *(hydrated sulphuric acid)* be added to 53 parts of carbonate of soda dissolved in water, a solution will be obtained in which neither acid nor alkaline characters can be detected.* But if more sulphuric acid or less soda be employed than the quantities stated, the neutral reaction of the solution will be destroyed. Therefore it will be evident that to ascertain the quantity of real or "available alkali" contained in a specimen of soda ash, it is merely necessary to discover the number of measures of dilute sulphuric acid of known strength which is required to exactly neutralize a given weight of it.

For the performance of the operations required in this method of alkalimetry, the following apparatus, &c., must be provided.

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* See Table of Equivalents.

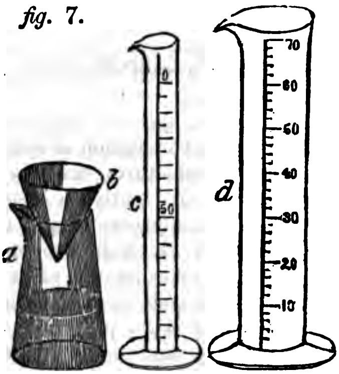


*fig.* 7.

A balance and a set of grain weights.

Two glass beakers of the form represented (in *fig.* 7. *a.*, or in *fig.* 3.) each capable of containing about half a pint of liquid.

A porcelain crucible capable of containing one ounce of liquid.

An alkalimeter, which is a tubular glass vessel, about 12 inches long, and ¾ of an inch in diameter, capable of containing rather more than 1000 grains of water. It is supported on a foot, and provided with a lip for pouring liquids, and graduated into 100 divisions, numbered from the top downwards. (*Fig.* 7. *c.*)

A glass jar, capable of containing the tenth of an imperial gallon of liquid (7000 grains,) graduated on the side into 100 divisions. (*Fig.* 7. *d.*)

Blue litmus paper.
Bicarbonate of soda.
Oil of vitriol.
Two quart bottles, with glass stoppers.
Distilled water.
Water bath, spirit lamp, and wire ring.

69. *Preparation of the Standard Test Acid.*

*a.* Measure 10 parts of commercial sulphuric acid; place the acid in one of the glass beakers, and add to it 50 parts of water; stir the mixture; and when it has cooled, ascertain its saturating power as follows :—

*b.* Place the porcelain crucible on one of the pans of the balance, and counterpoise it by pieces of lead placed on the other pan. Introduce into it about 1 oz. of bicarbonate of soda, and heat it strongly for a quarter of an hour over the spirit lamp. By exposure to heat, this salt is deprived of a portion of its carbonic acid, and a pure anhydrous carbonate of soda is obtained. The crucible, when sufficiently cool to handle, is to be set again on the balance, and weights amounting to 171 grains being placed on the pan with the counterpoise, portions of the carbonate are to be removed from the crucible until the equilibrium is exactly restored.

*c.* Shake the anhydrous carbonate into the solution glass (*fig* 7. *a.*), and dissolve it in about a wine-glassful of water, taking care to rinse out the crucible with water, which is to be added to that in the glass. Place the glass on the water bath, so as to heat the solution to boiling.

*d.* Fill the graduated glass, "the alkalimeter," (*fig.* 7. *c.*) up to the mark 0 with the dilute sulphuric acid (*a.*), and add it, little by little, to the solution of carbonate of soda (*c.*), and after each addition of the acid, stir the mixture for a second or two with a glass stirrer, and remove a drop of it on the rod and place it upon a slip of blue litmus paper. Continue slowly to add the acid, until a drop of the solution produces a red mark on the paper. If the red tint disappear upon drying the paper on the top of the water bath, it depends merely upon the carbonic acid liberated, and not upon the presence of an excess of sulphuric acid. The addition of the acid should be cautiously made, until the red stain which a drop of the solution produces on the test paper, is not removed by heat. The alkalimeter should then be allowed to remain at rest, so that any acid adhering to the side of the tube may drain down, and the number of measures of the acid consumed observed. It will be recollected that 171 grains of anhydrous carbonate of soda were directed to be employed in the preparation of the alkaline liquid. This quantity of carbonate contains 100 grains of soda, so that the number of measures of the dilute acid which have been added to it from the tube, contain exactly the quantity of absolute sulphuric acid required to neutralize that amount of soda; and thus, having ascertained the *strength* of the test,—that is, its neutralizing power, it will be obvious that we may employ it to discover the proportion of soda, or of the carbonate of that alkali, which may be present in a sample of soda ash; or of potash or its carbonate, in *potashes.*

It is, however, in practice found more convenient to dilute the acid, the strength of which we have ascertained, so that exactly 100 measures of it may neutralize 100 grains of soda. This is readily effected by placing the whole quantity of the test in a large graduated jar (*fig.* 7. *d.*), and adding to it water, so as to make up the number of volumes, shown by experiment to be sufficient to neutralize 100 grains of soda, to 100 volumes. Thus, suppose 80 measures of the test acid were consumed in our experiment, we require to add 20 volumes of water to every 80 volumes of the test acid. A quart of the dilute acid may be prepared and preserved for use in a stoppered bottle; and in order to be certain that the proper quantity of water has been employed in diluting it, its strength should be again ascertained by the methods already described (*b.* to *d.*).

70. The method of alkalimetry above described is that which is usually employed for commercial purposes in this country. The results, however, are only to be regarded as correct when the sample of ash contains *no substances in addition to the carbonated alkalies capable of neutralizing the test acid*, and interfering with the accuracy of the indications afforded by the quantity of it consumed in our experiments. Both in the soda ash and potash of commerce, there are certain compounds almost invariably present, though usually only in small quantities, which possess this property; and if overlooked in the examination, as is frequently the case in commercial analyses, may lead the purchasers to conclude that the sample contains a larger amount of real alkali than is actually present. The following are the impurities or extraneous substances usually found in the ashes of plants, and in crude soda ash.

1. *Soluble in water*—

| In potash, and the ashes of plants. | In soda ash. |
|---|---|
| Sulphate of potash. | Sulphate of soda. |
| Chloride of potassium. | Chloride of sodium. |
| Silicate of potash. | Sulphides of sodium and calcium. |
| Phosphate of potash. | Silicate of soda. |
| Manganate of potash. | Hyposulphite of soda. |
| Organic matters. | Sulphite of soda. |
| Sulphide of potassium. | |

2. *Insoluble in water*—

| | |
|---|---|
| Silicate, phosphate, and carbonate of lime.<br>Phosphate and carbonate of magnesia, oxides of iron and manganese, sand, and charcoal. | Lime.<br>Carbonate of lime, sand, and charcoal. |

In purified soda ash, the only constituents present will be those which are soluble in water; and by dissolving either barilla or crude soda in water, and filtering the solution, the *carbonate of lime*, &c., which would neutralize a portion of the test acid, may be removed, but the *sulphite and hyposulphite of soda*, and the *sulphides of sodium and calcium*, which, if present, will also take up the acid, cannot, by any convenient means, be prevented from interfering with the accuracy of the process; and, therefore, in such cases it is indispensable that another method of examination should be employed. (*See* 72.)

71. *Preliminary examination of the sample, in order to determine the method of alkalimetry to be adopted.*—In proceeding to examine a sample of ash, the presence or absence of the compounds which interfere with the accuracy of the ordinary methods of alkalimetry should be determined. For this purpose—

*a.* Add some dilute sulphuric acid to a portion of the sample. If the putrid odour of sulphuretted hydrogen is evolved (*Confirm* 61. II.), it contains a *sulphide.*

*b.* Pour about two tablespoonfuls of dilute sulphuric acid into a glass, and add solution of *chromate of potash*, so as to give it a yellow colour (*Fresenius and Will*); add about a teaspoonful of the ash to the liquid (taking care not to neutralize the acid). If the solution does not lose its yellowish colour, neither *sulphite* nor *hyposulphite of soda* is present; but if it is rendered green, one of these compounds is contained in the sample, and the method described at (72.) must be employed to ascertain the amount of alkali.

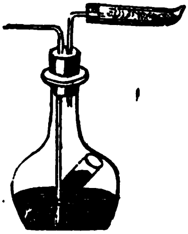
*c.* A portion of the ash is placed in the beaker (*fig.* 7. *a.*), and hot water poured upon it, and the solution placed in a filter. If a residue, insoluble in water, remains, it should be washed with more water, and if, on the addition to it of *hydrochloric acid*, effervescence is produced, *carbonate of lime* or *carbonate of magnesia* is present; and the sample, before examination, must be dissolved in water, and the insoluble matters separated by filtration, and the filtrate tested by (69.) or (72.) as may be found necessary. *(See a. and b.)*

*d.* As many samples of soda ash and of potash contain, in addition to carbonated alkali, a portion of *caustic alkali*, the presence of which would interfere with the accuracy of the results obtained by the method of alkalimetry described at (72.), it is necessary to ascertain its presence or absence by the following process. Mix one part of the sample with about three parts of crystallized *chloride of barium*, and place the mixture in a beaker, and pour upon it enough hot water to cover it, stir the mixture, and filter a portion of it, and add to it a drop of *chloride of barium* solution, which, if it affords no precipitate, is a proof that a sufficient amount of the salt has been already used. If, however, the filtrate is rendered turbid on the addition of the test, some more *chloride of barium* must be added to the mixture. If the filtrate, when examined with a slip of red litmus paper, is found to possess an alkaline reaction, the sample contains a *caustic alkali*.

72. The use of the test acid in determining the per-centage of carbonated alkali which a sample of ash contains, is based upon the principle, that as the amount of *alkali* which exists in the carbonate is definite and invariable, we can, by ascertaining the quantity of an acid of known strength which forms a neutral compound with it, calculate the proportion of carbonate which it represents; so, also, a second method for the examination of carbonates is employed, in which the object is to determine exactly the amount of the alkali or carbonate, by ascertaining the quantity of carbonic acid in the compound. The usual process for this purpose employed, consists in decomposing a known quantity of the carbonate placed in a vessel with an excess of acid, so as to expel the carbonic acid, the amount of which is ascertained by the loss of weight

observed. For the success of this method, it is essential that all the alkali contained in the sample should exist in the form of a neutral carbonate, and that no compound *(sulphides or hyposulphites)* should be present, which, when acted on by the acid, would disengage volatile gases. The sources of error, however, presented by the presence of such compounds, may be readily obviated in the application of this method of alkalimetry, by the use of the means directed at (73. II). The most simple and easily constructed form of apparatus for effecting the decomposition of the carbonate, so as to admit of the accurate determination of the carbonic acid expelled, without the loss of any other ingredient, is that represented (*fig.* 8.), and consists of a light glass flask, capable of containing about 6 oz. of water, closed by means of a cork perforated by two holes, through one of which a piece of tube, bent at right angles above the cork, is passed, which, by means of a perforated cork, is connected with a second tube about three inches long, drawn out at one end, so as to leave only a small opening. The larger tube is filled with fragments of *chloride of calcium*. Through the other hole in the cork, a thin glass tube, of the form shown in the engraving, is passed, so as to reach almost to the bottom of the flask. The opening of this tube is closed with a little stopper of wax. A weighed quantity of the sample is introduced into the flask, with about 1 oz. of water; and a test tube of such size, that when placed in the flask, it will stand in the position shown in the figure, without being overturned, is filled with sulphuric acid, and introduced by means of a pair of pincers, taking care not to allow any of the acid to fall into the flask. The cork, with its tubes, is now carefully adjusted to the neck of the flask, and the whole apparatus placed on the balance, and accurately counterpoised by pieces of lead. The flask is then removed from the balance, and inclined so as to allow some of the acid to run out of the tube into the solution. Carbonic acid will be disengaged with effervescence, and will escape through the chloride of calcium tube, while any watery vapour which

*fig.* 8.



accompanies it will be retained. When the effervescence produced has ceased, some more acid is poured out of the little tube, and so on, until all the carbonic acid is expelled. When the decomposition of the carbonate is completed, the flask is warmed over the water bath for some minutes, and the plug of wax withdrawn from the tube, and any carbonic acid remaining in the flask removed, by applying the mouth to the chloride tube, and sucking air through it until no taste of carbonic acid is perceived. The flask is now to be replaced on the balance, and the loss of weight will indicate the carbonic acid which was contained in the specimen examined, and enable us to calculate the proportion either of carbonate or of available alkali. Thus, by referring to the table given in the appendix, it will be seen that 53 parts of carbonate of soda consist of 22 parts of carbonic acid, in chemical combination with 31 parts of soda, so that by a simple calculation we can readily ascertain the amount of SODA represented by the weight of carbonic acid. Thus, suppose the loss of weight to be 8 grains, the calculation will be as follows:—

$$22 : 31 :: 8 : 11{\cdot}27.$$

73. The operations necessary in the examination of a sample of soda ash, barilla, or potash are to be conducted as follows:—

I. *Determination of the amount of water.* Weigh 100 grains of the sample, and heat for half an hour in a porcelain crucible over the spirit lamp; allow the crucible to cool, and ascertain the loss of weight, which represents the WATER present in the sample.

II. *Determination of the amount of carbonated alkali.*

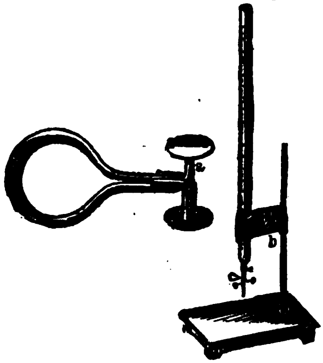
*a.* Weigh 50 grains of the sample. If it does not entirely dissolve in water, pour hot water upon it; and place the insoluble matters upon a filter, which may be supported by a narrow-mouthed solution beaker (*fig.* 7. *a.*), and wash the filter with water until the liquid which flows through it ceases to possess an alkaline reaction when examined by red litmus paper. If the sample has been found not to contain any of the compounds which interfere with the use of the acid, test it exactly as directed at (69. *d.*); but if the presence of any of these compounds has been discovered, concentrate the solution by evaporation until its volume is reduced to about one ounce, and introduce it into the carbonic acid apparatus (*fig.* 8.), and add to it half a teaspoonful of *chromate of potash*, by which any impurities which would evolve volatile gases when acted on by the acid, are oxidized and converted into fixed compounds; and proceed as directed at (72.).

*b. The sample contains caustic alkali* (71. *d.*). If none of the other extraneous matters indicated (71.) are present, examine it by the test acid (69. *d.*); but if any of these is present it is necessary to examine it by the second method, and to convert the caustic alkali into a neutral carbonate, for which purpose, after having ascertained the amount of water by (73. I.), weigh 50 grains of the dry sample in the crucible, and rub it in a mortar with 100 grains of dry flint sand (free from carbonates,) and 20 grains of carbonate of ammonia in powder. Place the mixture in a porcelain capsule, moisten it with solution of *carbonate of ammonia*, and heat gently over the lamp until it is rendered completely dry. Allow the mass to cool, and transfer it to the gas apparatus, and wash out the capsule with water, and add the rinsings to the flask. All the alkali present will now be in the form of carbonate, and may, after the addition of a little *chromate of potash*, be examined by (72.).

III. *Determination of the amount both of the caustic and carbonated alkali which a sample, when both are present, may contain.* Determine, in the first place, the amount of carbonic acid contained in the specimen, *after* treatment with carbonate of ammonia, &c., as directed above (II. *b.*), and make a second experiment to ascertain the quantity of carbonic acid contained in the specimen *before* being heated with the carbonate of ammonia. The first experiment will give both the carbonic acid originally present and that which the caustic alkali has obtained from the carbonate of ammonia, while the second will give merely the quantity of carbonic acid corresponding to the carbonated alkali of the sample; so that by subtracting the amount of the original carbonate from that which corresponds with the result of the first trial, the difference will be an amount of carbonate which will represent the proportion of caustic alkali in the specimen. Another method is sometimes adopted, which consists in ascertaining by the test acid (69. *d.*) the entire amount of alkali in the specimen, and afterwards to decompose and remove the carbonate, by adding to a second weighed portion of the sample, chloride of barium, as directed at (71. *d.*). The solution is to be filtered, the insoluble matter washed, and the quantity of alkali in the filtrate, which corresponds with the caustic alkali of the sample, determined by the test acid.

74. *New form of Alkalimeter.*—In all operations in which the application of standard test solutions is required, a form of alkalimeter, invented by an ingenious German chemist (Dr. Mohr, of Coblentz), will be found to possess many advantages. It consists of a graduated glass tube, numbered like the ordinary alkalimeter, from the top downwards (*fig.* 9.), and drawn out to a small tubular orifice at the lower extremity. To this extremity, a narrow tube of vulcanized India rubber, about one inch in length, is fixed, into the lower end of which a short glass tube, with a fine opening, is inserted, and secured so as to leave some space between the ends of the two glass tubes. Upon the space left between the tubes, a simple clamp, formed of strong brass wire, of the shape and about twice the size of (*fig.* 9. *a.*) is secured, so that the two straight wires of the clamp may press upon and close the elastic tube, and again allow it to open, when by pressure upon the ends of the wires they are separated. The instrument thus constructed is supported on a stand, and when it is to be used, the test solution is poured into it through a funnel, until it is filled above the 0 mark,

*Fig.* 9.



and then by pressing upon the ends of the clamp the elastic tube is opened and the solution allowed to flow out into a beaker placed under it, and when it has descended, so that the bottom of the curve which the liquid forms in the tube exactly corresponds with the zero line, the fingers are removed, and the tube closed.

## DETERMINATION OF THE AMOUNT OF LIME CONTAINED IN LIMESTONES, MARLS, AND SOILS.

75. The little apparatus (*fig.* 8.) used for the determination of the carbonic acid in alkaline carbonates, may be advantageously employed to estimate the amount of lime, or of carbonate of lime, in limestones, marls, and soils. The quantity of the specimen to be submitted to examination for this purpose should be regulated by the proportion of carbonate which it may be supposed to contain. Thus, of substances rich in carbonate of lime (*limestones, &c.*) 25 grains may be taken, while 50 grains of a marl, and 100 grains of a soil will be suitable quantities to operate upon. The specimen dried on the water bath (if a rock previously broken into small fragments) is to be introduced into the flask with about half an ounce of water, and the operation conducted exactly as described at (72.). As, however, sulphuric acid forms a sparingly soluble compound with lime, hydrochloric acid or nitric acid is to be substituted for it, as by the employment of either of these acids, the complete decomposition of the carbonate can rapidly be effected. Having ascertained the weight of the carbonic acid evolved, and knowing (see *Table of Equivalents*) that 50 parts of *carbonate of lime* consist of 28 parts of *lime* in chemical combination with 22 parts of *carbonic acid*, we can readily calculate the amount of lime, or of carbonate of lime, represented by the displaced carbonic acid.* Thus, suppose the loss of weight observed in experimenting with 25 grains

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* If, however, the specimen has been found to contain any considerable amount of carbonate of magnesia, it will be necessary, for the exact determination of the quantity of lime, to filter the acid solution, and to proceed as directed at (65. IV. *a. b.*)

of limestone to be 8 grains, the quantity of carbonate of lime present will be calculated as follows :—

22 : 50 : : 8 = 18·18, which number multiplied by 4 will give the per-centage of CARBONATE OF LIME in the specimen (18·18 × 4 = 72·72).

## METHODS EMPLOYED TO ASCERTAIN THE AMOUNT OF CARBON, HYDROGEN, OXYGEN, AND NITROGEN, IN ORGANIC BODIES.

76. To persons unacquainted with the interesting processes by which the chemist is enabled to ascertain with certainty the proportions of the organic elements which compose the combustible part of animal and vegetable substances, the following outline of the methods adopted may be useful. The principle upon which the chemist proceeds in his operations for this purpose, is to convert the elements, carbon, hydrogen, &c., into compounds of known composition and established properties; and this he effects with respect to the carbon and hydrogen of the substance examined, by *oxidizing* them, so as to convert the former into carbonic acid, and the latter into its familiar compound, water. The weight of these compounds formed in his experiments being ascertained, it is easy, from their respective amounts, to calculate the proportions of carbon and hydrogen which they represent. Thus, 22 parts by weight of carbonic acid represent 6 parts of carbon; and 9 parts by weight of water represent 1 part of hydrogen.* The oxygen is not directly determined, but the weight of the other elements being ascertained, the remainder of the weight of the substance represents the amount of oxygen contained in it. For the estimation of the amount of nitrogen, a separate experiment with another portion of the substance is made, and that element is forced to enter into combination with hydrogen, so as to assume the form of its well known compound, ammonia, which is collected in a tube of peculiar form (*fig.* 11. *a.*), in which some hydrochloric acid

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* See the Table of Chemical Equivalents in the *Appendix*.

*(muriatic acid)* is placed. The amount of the ammonia absorbed by the acid solution can be readily ascertained by simple means, and from its weight the nitrogen of the substance examined calculated; as it will be recollected that every 17 parts by weight of ammonia represent 14 parts of nitrogen. Usually the acid solution is mixed with some bichloride of platinum, a substance which combines with the ammonia contained in it, so as to produce a solid compound of definite composition, which can be collected on a filter, and from the weight of which, when dried at 212°, the exact quantity of nitrogen evolved in the form of ammonia can be calculated. The apparatus employed in these processes consists, for the determination of the carbon and hydrogen, of a long tube of hard glass (*fig.* 10. *a.*), in which a known weight of the substance to be examined, previously dried, so as to remove every trace of moisture, is placed, together with oxide of copper, a compound which serves as the oxidizing agent, having the property of yielding up its oxygen on being heated. This tube is closed at one end, and at the open end, connected by means of a cork with a second tube (*fig.* 10. *b.*) filled with *chloride of calcium*, a substance which has a remarkable power of absorbing moisture, and the chloride of calcium tube is joined by means of a caoutchouc tube (*fig.* 10. *c.*) with a glass instrument, consisting of several bulbs, in which a strong potash ley is placed (*fig.* 10. *m.*). When the long tube containing the substance to be examined, and the oxidizing material, is thoroughly heated, by surrounding it with a fire of charcoal in the furnace represented in the illustration, the carbon and hydrogen combine with the oxygen of the oxide of copper, and are evolved in the form of water and carbonic acid, the former of which is detained by the chloride of

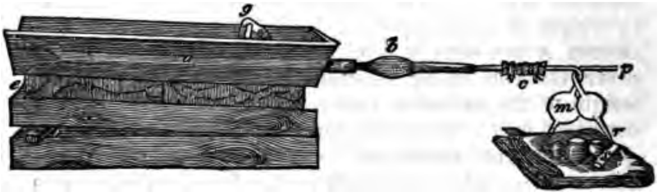

*Fig.* 10.

calcium while the latter is absorbed by the solution of potash. The weight of the receivers, with their contents, having been previously ascertained by an accurate balance, their increased weight at the conclusion of the experiment shows the amount of carbonic acid taken up by the potash, and of water absorbed by the chloride of calcium, and consequently enables us to calculate the amount of carbon and hydrogen contained in the specimen. The apparatus for the determination of the amount of nitrogen consists of a glass combustion tube like that just described; but instead of oxide of copper, the substance to be examined is mixed with an alkali (in practice a mixture of caustic lime and soda is for various reasons preferred), by the influence of which, when heat is applied, all the nitrogen present is made to escape in the form of ammonia, which is absorbed by hydrochloric acid contained in the bulb tube (*fig.* 11. *a.*). By pouring out the acid liquid from the bulb tube and adding to it, as already stated, bichloride of platinum, a solid compound containing all the ammonia present is obtained. The potash bulb (*fig.* 10. *m.*) is the invention of Baron Von Liebig, and is generally regarded as having contributed in no small degree to the progress of organic chemistry, by the assistance which it has afforded in the accurate determination of carbon, while for the nitrogen process we are indebted to Messrs. Varrentrapp, and Will.

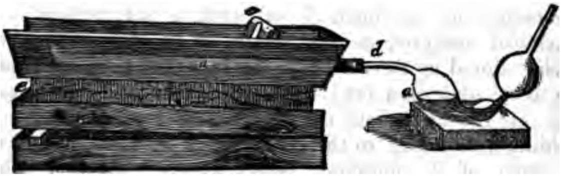

*Fig.* 11.

77. The presence of nitrogen in an organic substance, when any considerable amount is present, is usually readily detected by the peculiar odour of singed feathers evolved when it is strongly heated, but when the proportion of nitrogen is very minute, the characteristic smell may not

perceptible, and other methods must be adopted. The most delicate for this purpose consists in placing the substance under examination in a small test tube, and adding to it a bit of the metal potassium, and applying heat. When the combustion which ensues is concluded, a small quantity of water is to be gradually introduced, and the solution, which, if nitrogen was present, contains cyanide of potassium, filtered. To this solution a drop or two of a solution of the common green vitriol (sulphate of iron) of the shops is to be added, and a slight heat applied; and if, upon adding to the mixture a sufficient amount of muriatic acid to render it acid, a bluish-green coloration be produced, the presence of nitrogen is demonstrated.

## CLASSIFICATION OF SOILS, AND METHODS BY WHICH THEIR PHYSICAL QUALITIES MAY BE ASCERTAINED.

78. A statement of the quantities of fertilizing matters contained in a specimen of soil, such as is furnished by its chemical analysis, merely serves as an inventory of the riches stored up for use in its treasury, but does not enable us to calculate how far the mass of capital is directly available for the immediate requirements of the cultivator. In addition, therefore, to the investigation of the kind and the quantity of the inorganic constituents of plants which a portion of soil contains, the examination of the state of division in which these substances exist in it is absolutely indispensable, correctly to estimate its agricultural value. A soil to be fertile must possess that *mechanical* or *physical* condition which will adapt it to the requirements of the crops grown upon it. These mechanical qualities must be carefully considered in our estimation of the characters of a soil, as they exercise an important influence not only upon the amount of nourishment which its own materials are capable in a given period of supplying to our crops, but upon its power of conveying to them the constituents of the air. It is also requisite that we should not overlook the influence which certain conditions not depending upon

its chemical or physical qualities, and beyond the control of the farmer,—as the temperature and fall of rain in the district in which it is situated, its elevation above the sea, and its inclination and exposure, exercise upon its fertility.

The inspection of the surface of a ploughed field after a heavy shower has fallen upon it, will be sufficient to show that it is composed of a finely divided pulverulent matter like clay, portions of which are washed by the rain into the furrows, and of fragments of decaying vegetable matters, and of particles of rocks of various sizes and colours, in the form of sand and gravel. If you drop upon the soil muriatic acid, an escape of bubbles of gas will lead you to conclude that carbonate of lime also enters into its composition. Soils may therefore be described as conisting of —1. *Finely divided clay.* 2. *Organic matters.* 3. *Sand and gravel;*—and 4. *Calcareous matters.* The relative proportions of these four classes of substances vary very much, as is well known, in our cultivated soils, and serve to determine both the names which are applied to them by the farmer, and the kinds of crops to which they are regarded as specially adapted. Thus, where sand and gravel predominate, the soil is loose and open, and is described as *light*, while the presence of a large amount of clay produces a *stiff* and intractable soil, which obstinately retains water. It is, therefore, important, that land-stewards, and the teachers of agricultural schools, should be enabled to ascertain the proportions in which these substances enter into the constitution of the soils which they cultivate, so as not merely to judge more correctly of their qualities, but to convey to others a more accurate idea of their characters, than in the vague and unsatisfactory local terms usually employed. Various methods of classification, founded upon the mechanical composition of soils, have been recommended by the agricultural authorities of France and Germany, and adopted in the agricultural institutions of the continent. Of these, probably the best are those based upon the researches of the celebrated agriculturist, Schübler; the following modification of which I have found useful in the instruction of my classes. It will be found a profitable exercise for the advanced pupils in the agricultural schools to examine soils from the Model and other farms, and to assign them their proper place in the systematic arrangement given in the table, which should be copied on a sheet of pasteboard, and hung up in the school-room:—

## CLASSIFICATION AND NOMENCLATURE OF SOILS.

| Name. | | Proportions of Sand, Clay, &c. |
|---|---|---|
| Containing *less* than 5 per cent. of *Carbonate of Lime*. | I. Pure Clay, | Leaves no residue of Sand when washed—Porcelain Clay. |
| | II. Tenacious Clay, | Leaves from 5 to 20 per cent. of Siliceous Sand—Brick Clay. |
| | III. Clay Loam, | Leaves from 20 to 40 per cent. of residue when washed. |
| | IV. Loamy Soil, | Leaves from 40 to 70 per cent of Sand. |
| | V. Sandy Loam, | Leaves from 70 to 90 per cent. of Sand. |
| | VI. Light Sandy Soil, | Leaves more than 90 per cent. of Sand. |
| Containing *more* than 5 per cent. of *Carbonate of Lime*. | VII. Marly Soil, | Yields from 5 to 20 per cent. of Carbonate of Lime. |
| | VIII. Calcareous Soil, | Yields more than 20 per cent. of Carbonate of Lime. |
| Containing *more* than 5 per cent. of *Organic Matters*. | IX. Garden Soil, | Contains from 5 to 20 per cent. of Organic matters. |
| | X. Peaty Soil, | Contains more than 20 per cent. of Organic matters. |

## SELECTION OF SAMPLES OF SOILS.

In selecting samples of soils for examination, take a pound or two of the soil from such portions of the field as approach most closely in appearance, colour, &c., and the productive powers of which have been found by experience fairly to represent its general qualities. These samples should be mixed together, and a pound taken from the mass, and enclosed in a strong sheet of writing paper, or placed in a wide-mouthed bottle. For examination of the peculiarities of the field it would be desirable also to examine an unmixed specimen taken from that portion of the field which is regarded as representing the prevailing character of the soil.

The operations necessary for the determination of the mechanical composition of the soil for the purposes of classification are very simple.

PROCESS I.—*Determination of the proportions of Clay* *and of Sand and Gravel contained in the Soil.*—Take about 4 oz. of the soil, and dry it thoroughly by exposing it to heat over the water bath. Weigh from the dried soil two separate portions. Let the weight of one portion (*a.*) be 500 grains, and let the other portion (*b.*) weigh 100 grains. Introduce the portion (*a.*) into a Florence flask with about half a pint of water, and boil for half an hour. Remove the flask from the lamp or fire, pour the hot mixture into a large tea cup, and allow it to remain at rest for *three minutes.* Then cautiously pour off the clear liquid with the matters—remains of roots and clay—suspended in it, taking care not to disturb the sediment, and by means of a spoon or wooden stirrer break up any lumps. Fill up the cup with water, stir briskly with the spoon, and again allow the liquid to remain at rest for three minutes, and pour off the floating matters, and repeat the washings, &c., until the water flows away clear. The heavy sand, fragments of rocks (stones and gravel), which were contained in the soil, will thus be separated from the finely-divided clay; and by washing the deposited matters out of the flask into a small cup or evaporating dish, draining away the wash water, and drying them by placing the cup near the fire or on the water bath, their weight may be ascertained by the balance. The difference between the weight found, and the quantity of soil (500 grains) introduced into the flask, will be the amount of clay and organic matters washed away. Thus, suppose, as in the case of a soil from the Munster Model Farm, near Cork, belonging to the Commissioners of National Education, lately examined in my laboratory, the *sand* and *gravel* deposited in the flask weigh 402·3 grains, the clay and organic matters of the soil will amount to 19½ per cent. Though not requisite in order to name and classify a soil, yet it may occasionally be useful to ascertain the relative amount of the sand and gravel composing the sediment. Their separation may be readily effected by means of a sieve formed of a piece of fine wire gauze.*

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* To obtain a knowledge of the relative amount of stones and finely-divided matters contained in a field, it will be useful to pass several cubic feet of earth through a sieve, the meshes of which are ¼ of an inch in diameter, and to ascertain the weight of the stones separated by the sieve.

Process II.—*Determination of the amount of Organic Matter contained in the Soil.*—For this purpose the second quantity of the dried soil (*b.*) is to be employed. Introduce this portion, the weight of which you will recollect was 100 grains, into a thin porcelain dish, and place the dish with its contents in one of the pans of the balance, and on the other pan place weights, or bits of sheet lead, so as exactly to counterpoise it. Next remove the dish and expose it to heat by placing it on a clear fire, or, what is to be preferred, by supporting it on a stand over the flame of a spirit lamp, until the black colour which the charred vegetable matter at the commencement of the operation communicates to the soil, has entirely disappeared; when this takes place, allow the dish to cool, and set it again upon the pan of the balance, and ascertain the loss of weight which the soil has experienced, which represents the amount of organic matter burned away, by placing weights on the same pan, so as to restore the equilibrium. Thus, 100 grains of the soil from the farm near Cork, when treated as described, was found to contain 3·9 grains of organic combustible matters.

Process III.—*Determination of the Amount of Carbonate of Lime contained in the Soil.*—Place about a teaspoonful of the soil in a wine-glass, and pour upon it a few drops of spirits of salts (*muriatic acid*); unless you observe an effervescence from the escape of bubbles of gas, it will not be necessary for you to ascertain the amount of lime, as you may in that case be certain that the soil contains *less than* 5 *per cent. of carbonate of lime.* (*See Table.*) If, however, an effervescence be observed, the amount of lime present may be determined with sufficient accuracy for the purpose of classification by the following method:—Take the portion of soil from which the organic matters have been removed by Process II., introduce it into a flask containing 1 oz. of spirits of salts, (*muriatic acid*), and 12 oz. of water, and allow the mixture to remain at rest for an hour. Prepare a funnel and filter, and pour upon the filter the contents of the flask, carefully washing out all the matters in the bottle with water. Pour water upon the filter until the liquid which passes through has no longer an acid taste. When the substance on the paper is sufficiently washed, dry it over the water bath, and remove it from the paper, and introduce it into a crucible, and heat it over the lamp, so as completely to drive away all moisture, and weigh it; the loss of weight will indicate (*rather more*) the amount of carbonate of lime present in the soil.

PROCESS IV.—*Determination of the Specific Gravity of the Soil.*—By the specific gravity or density of a soil is understood the weight of a portion of soil compared to that of an equal bulk of water. Thus, it is found that soils containing much vegetable matter, are *specifically* lighter than those which are chiefly composed of sand, and though soils which, like bog earth, almost entirely consist of organic matter, are unfertile, yet experience shows that those which, like garden mould, contain a considerable amount of it, are more productive than sandy soils, in which it is deficient. The determination of the specific gravity of a soil may be most readily effected by taking a common phial, capable of containing about 2 oz. of water, scratch a line on the neck with a file, and fill the bottle up to the mark with distilled water, and place it on one of the pans of the balance, and counterpoise it by placing a pill box containing shot on the other pan. Then place 500 grains on the same pan with the bottle, and pour out water from the bottle until the equilibrium is restored. By this means you obtain in the bottle a *space equal to the bulk* of 500 grains of water. The next part of the operation consists in introducing into the bottle a sufficient quantity of the thoroughly dried soil to cause the water to ascend again to the mark on the neck. The soil should be introduced in small quantities at a time, and the bottle occasionally shaken, so as to expel any bubbles of air. Next ascertain the weight of the soil introduced, that is, the weight required to fill the space previously occupied by 500 grains of water, by placing weights in the pan of the balance which contains the counterpoise. The number of grains required to restore the equilibrium, multiplied by two, will show the specific gravity of the soil, as compared with 1,000 grains of water, which is taken as the standard of density for solids and liquids.

In calculating the amount of fertilizing ingredients which a soil is capable of yielding for the support of plants, a more satisfactory estimate is afforded to the farmer by considering the quality which will be available in a given breadth, than merely by the statement of its per-centage composition. In such calculations of the store of mineral food in the soils, usually the estimate of the German chemist, Krocker, is adopted, and the weight of one acre of soil, one foot deep, is regarded to be equal to 3,000 tons. Thus, suppose a soil is found by the chemist to contain, like that of the Albert Model Farm (No. 1), 0·06 per cent. of phosphoric acid, this apparently trifling quantity amounts, per statute acre, to 4·032 lbs. or 36 cwts.

In addition to the simple operations described, the pupil may also examine whether the soil possesses acid characters, that is, whether it be "sour," and also its power of absorbing and retaining water.

Process V.—*Examination for Acidity.*—This is readily effected by introducing a portion of the soil (about 2 oz.) into a clean Florence flask, and adding a sufficient quantity of distilled or filtered rain water to cover it, and boiling over the lamp for fifteen minutes. Allow the solid matters to subside, and pour off the clear liquid, and place in it a slip of *blue* litmus paper. If the paper be rendered red, the soil may be regarded as *sour*, and will be improved by the application of lime.

Process VI.—*Determination of the Power produced by the Soil of Retaining Water.*—Prepare a couple of filters of equal size, and place one inside the other, in a funnel supported by a stand and ring, as shown in the annexed figure. Upon the double filter, so arranged, place 1,000 grains of perfectly dry soil, and pour water upon it until it appears completely wet, and the water begins to drop through the funnel; allow it to remain at rest until no water escapes, and remove the wet earth with the filters,

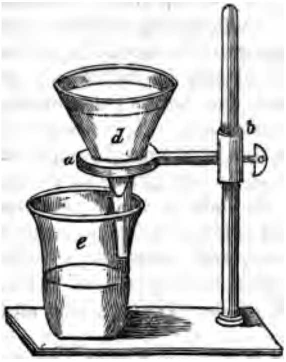


*Fig.* 12.

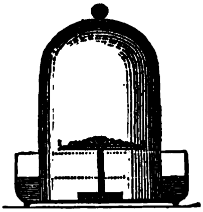
and place the outer filter in one pan of the balance, and that containing the earth in the other, and ascertain the increase of weight over the 1,000 grains of soil employed, which will be the amount of water absorbed and retained by the soil. Thus it has been found by experiment, that from 1,000 grains of siliceous sand treated as described, water will begin to drop when the sand has absorbed 250 grains, while garden mould will retain so much as 890 grains.

The power which a soil possesses of retaining water within its pores must materially influence its productiveness. Thus, soils which allow the water too rapidly to pass through them will, in seasons in which but little rain falls, be incapable of supplying plants with the necessary amount of inorganic constituents. It will be also evident that in countries like Ireland, in which showers are so frequent, soils which are too retentive of moisture will be *cold* and unfavourable to the full development of plants.

PROCESS VII.—*Rapidity with which the Soil dries after Rain.*—Spread the soil saturated with water, as in PROCESS VI., and the filter, containing it, on a plate, and expose it to the air in a room, the windows of which are open, or in the open air, for four hours, and ascertain the loss of weight, which will indicate the amount of moisture separated from the specimen. Experiments show that the rapidity with which soils dry, and their power of retaining moisture, influence both the quality and produce of our crops. Soils containing a large amount of sand dry rapidly, while evaporation is delayed in proportion to the amount of decaying organic matters present.

PROCESS VIII.—*Power of the Soil to Absorb Moisture from the Air.*—Like all porous bodies, the soil draws into itself the ingredients of the air, and especially the aqueous vapour which it contains. It has been calculated that the water supplied by rain would not be sufficient to yield plants the enormous amount of water requisite for their growth, and that the aqueous vapour condensed within the pores of the soil, is the main source of its supply. Soils rich in vegetable matter are those which drink in aqueous vapour most eagerly, and thus its presence adds to their fertility. Those soils also which are good condensers of moisture are distinguished by their power of abstracting carbonic acid and ammonia from the atmosphere. In dry seasons, this property of the soil is especially to be regarded, as it enables the plant, during the night, to recover the moisture evaporated by the sun's heat.

Fig. 13.



The power of absorption of a specimen of soil may be ascertained as follows:—Spread 1,000 grains of thoroughly dried soil on a saucer, and set the saucer on a flat dish in which there is a small quantity of water, or support it on a stand, as shown in (*fig.* 13); invert over it a wide-mouthed glass jar about ten inches in length, such as is used by the confectioners, so as to rest with its mouth in the water contained in the dish. The experiment should be conducted in a room where the vessel will be protected from the direct influence of the sun, and the temperature of which is maintained as uniform as possible. After being allowed to stand 24 hours, the soil should be removed, and the increase in weight which it has experienced, which will represent the amount of moisture absorbed, ascertained by the balance. Experiments conducted in the manner just described, show that while pure siliceous sand and gypsum possess scarcely any power of absorbing moisture from the air, humus (decaying vegetable matter), is distinguished by its absorbent qualities.*

It will be obvious that while the amount of sand and gravel which remain after washing away the clay may assign the soil a place among the sands, clays, &c., included in the first six classes of the table, the proportion of carbonate of lime dissolved out by muriatic acid (PROCESS III.) may exceed 5 per cent., and thus also entitle the soil to the denomination of marly or calcareous. In such cases, it must be described in accordance with its constitution, by the addition of the term *marly* or *calcareous* to the character assigned to it by PROCESS I., and the same system is to be adopted with such soils as, by PROCESS II., are found to contain more than 5 per cent. of organic matters. Thus, a soil which, like that of the Albert Model Farm, is found by PROCESS I. to have 75·2 per cent. of *sand and small stones*, would, if by PROCESSES II. and III. the lime and organic matters were shown to amount respectively to less than 5 per cent., be termed simply a *sandy loam* (CLASS V.) ; but when containing, like the Albert soil, 10 per cent. of carbonate of lime and 14 per cent. of organic matters, its correct designation would be *marly garden sandy loam.*

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* I have not given any directions for the quantitative chemical analysis of soils, because I consider that to obtain trustworthy results requires not merely an amount of chemical knowledge, but of practical skill in analytical operations, only to be acquired by training in the laboratory. The methods described for the examination of the physical qualities of soils will, however, afford the farmer much useful information. In schools, where the proper facilities exist, the pupils may advantageously be occupied in the investigation of the kinds of matters soluble in water which soils contain, according to the processes described. (63. and 64.).

79. In describing the characters of a soil, the pupil should be instructed to attend to the following points :—

1. The district in which it is situated.
2. Its elevation above the sea.
3. Its inclination and exposure.
4. The Geological formation upon which it rests.
5. Its place in the classification, and general chemical composition.
6. Its specific gravity.
7. Its tenacity, and power of absorbing and retaining water.
8. Its colour.
9. Its depth, and the nature of its subsoil.
10. The weeds which prevail upon it.
11. Qualities and produce of the crops grown upon it.
12. Such additional information as may appear useful with respect to drainage, annual fall of rain, period of harvest, rent, price of labour, distance from markets, facilities of carriage, and for obtaining supplies of lime, sea weed, and other manures.

### EXAMPLES.

The following statements of the results of the mechanical and chemical examinations of the soils and subsoils of two of the Model Farms belonging to the Commissioners of National Education, will afford examples of the application of the methods described. The numbers given below correspond with those attached to the questions (79.) :—

### No. 1.—Soil of the Albert Model Farm.

1. The farm in connexion with the Albert National Agricultural Training Institution is situated about three miles north of Dublin.

2. The maximum elevation above the level of the sea is 172 feet, and its minimum 148 feet.

3. The greater portion of the farm has a slight inclination to the south.

4. Calp.

5. Mechanical Composition of the soil and subsoil. 100 parts of each respectively consist of—

By Process I.—

| | Soil. | Subsoil. |
|---|---|---|
| Clay and finely divided matters, | 24·71 | 28·32 |
| Sand and small stones, ... | 75·29 | 71·68* |
| | 100·00 | 100·00 |

By Process II.—

| | | |
|---|---|---|
| Organic matters, ... ... | 14·21 | 3·64 per cent. |

By Process III.—

| | | |
|---|---|---|
| Carbonate of lime, ... | more than 5 and less than 20 per cent. | more than 5 and less than 20 per cent. |

---

* Consisting of coarse granules of blackish limestone, grey chert, (an admixture of limestone and flint,) and calcareous sand.

| DENOMINATION ACCORDING TO THE TABLE, .. .. .. .. | *Marly Garden Sandy Loam.* | *Marly Sandy Loam.* |
|---|---|---|
| CHEMICAL COMPOSITION. 100 parts of each contained respectively— | | |
| Organic matters, ... ... ... | 14·21 | 3·64 |
| Potash, ... ... ... ... | 0·36 | 0·07 |
| Soda,... ... ... ... ... | 0·18 | 0·04 |
| Alumina, ... ... ... ... | 1·32 | 0·75 |
| Oxide of iron, ... ... ... | 1·82 | 4·22 |
| Lime, .. ... ... ... | 5·57 | 6·56 |
| Magnesia, ... ... ... .. | 0·06 | 0·02 |
| Sulphuric acid, ... ... ... | 0·22 | 0·19 |
| Phosphoric acid, ... ... ... | 0·06 | 0·03 |
| Chlorine, ... ... ... ... | 0·28 | 0·18 |
| Silica, ... ... ... ... | 0·55 | 0·07 |
| Carbonic acid, ... ... ... | 4·33 | 5·02 |
| Insoluble siliceous matters, ... | 70·82 | 78·66 |
| | 99·78 | 99·45 |
| Nitrogen per cent.,... ... ... | 0·29 | 0·18 |
| Water in the sample analyzed, ... | 22·30 | 14·20 |

6 Surface soil specific gravity, 2·25; subsoil specific gravity, 2·43.

7. *Power of Retaining Moisture.*—1000 parts of surface soil retained 688 parts; of subsoil, 484 parts of water.

*Rapidity with which the soil dries when exposed to the air.*—Of the water which the specimens had imbibed, in four hours the surface soil lost by evaporation 17·8; the subsoil, 30·6 per cent.*

8. The soil is of a brownish colour.

9. The depth of surface soil averages from 8 to 12 inches.

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| | | |
|---|---|---|
| * Weight of dry soil,... ... ... ... | 1000 | grains. |
| „ saturated with moisture,... ... | 1688 | „ |
| Difference, ... ... ... | 688 | |
| Exposed to the air for four hours, weighed | 1566 | |
| Loss by evaporation, ... ... ... | 122 | |

then 688 : 122 : : 100=17·8 per cent.

The produce of the farm is of a good average quality.*

The period of the harvest is tolerably early.

The surface soil is of a friable character, and has a medium power of retaining moisture, but the subsoil is a pretty retentive clay, intermixed with occasional layers of limestone gravel.

In trenching, care must be observed in bringing up but a small portion of the subsoil to the surface, as experience has proved that a large admixture of it is injurious to vegetation.

Within the last eight years a considerable portion of the farm has been thorough drained to a depth averaging from three-and-a-half to four-and-a-half feet, and the good effects of this depth of drainage are very marked, when compared with a system of shallow drainage which had been executed previously; so imperfect, indeed, was the latter system, that it was found necessary to *re*-drain the land.

From the farm being so close to the city of Dublin, the rent is very high, averaging £3 19s. 3d. per statute acre.

The entire labour of the farm is performed by the class of pupils in training.

Lime can only be obtained at a high price, averaging from 1s 8d to 2s per barrel of four bushels, and sea weed is not available for manuring purposes.

In addition to the farm-yard manure which is applied to the crops, and which is made on the farm, guano and vitriolized bone compound are used to a small extent.

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* Acreable produce of crops grown on the Albert Model Farm for three years, viz.:—from 1853 to 1855, inclusive:—

| | | | |
|---|---|---|---|
| Wheat, ... ... ... ... | 140 | stones | per statute acre. |
| Oats, ... ... ... ... | 150 | " | " |
| Barley, ... ... ... ... | 130 | " | " |
| Beans (Winter), ... ... | 120 | " | " |
| Potatoes, ... ... ... | 10 | tons | " |
| Turnips, ... ... ... | 20 | " | " |
| Mangel, ... ... ... | 24 | " | " |
| Carrots, ... ... ... | 8 | " | " |
| Parsnips, ... ... ... | 7 | " | " |
| Cabbage, ... ... ... | 40 | " | " |

WILLIAM BOYLE.

Albert Model Farm,
29th July, 1856.

The liquid manure which is collected from the cattle-houses, pupils' dormitories, water-closets, lavatories, &c., is applied by means of steam power on a portion of the Italian rye grass grown on the farm, and the produce is very considerable, the total amount of three cuttings this season (1856) has averaged rather more than 23 tons per statute acre. The first cutting commenced on the 14th of April, and the third on the 19th of July. It is expected that there will be at least two additional cuttings this season.

The fall of rain during a year, as stated by Mr. Moore, Curator of the Royal Dublin Society's Botanic Garden, is about 26 inches—it varies from 20 to 28, but seldom more.

### NO. 2.—SOIL OF THE MUNSTER MODEL FARM.*

1. 2½ miles due west of the city of Cork.
2. About 80 feet above the sea.
3. It has a gentle inclination to the south and west.
4. It rests upon the limestone formation, but is chiefly composed of the debris of the sandstone of the adjoining districts.
5. MECHANICAL COMPOSITION of the soil and subsoil. 100 parts of each respectively consisted of—

| | Soil. | Subsoil. |
|---|---|---|
| By PROCESS I.— | | |
| Clay ... ... ... ... | 19·53 | 11·26 |
| Sand and small stones ... | 80·47 | 88·74 |
| | 100·00 | 100·00 |
| By PROCESS II.— | | |
| Organic matters ... ... | 3·93 | 2·05 pr. cent. |
| By PROCESS III.— | | |
| Carbonate of lime ... | less than 5 pr. cent. | less than 5 pr. cent. |

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* The soils were examined in the Laboratory of the Chemico-Agricultural Society of Belfast. The Report on the Albert Model Farm was kindly supplied by Dr. Kirkpatrick, Head Inspector of Agricultural Schools, who has so usefully exerted himself to increase the efficiency of these institutions. The report on the Munster Model Farm was supplied by the manager, Mr. D. Cunningham. I take this opportunity of acknowledging the ready co-operation which has on all occasions been afforded to me by the teachers of the Albert School, and of the other schools of the Board of Education, in inquiries connected with these establishments.

| DENOMINATION, ACCORDING TO THE TABLE, CLASS V., .. .. .. | *Sandy Loam.* | *Sandy Loam.* |
|---|---|---|
| CHEMICAL COMPOSITION. | | |
| 100 parts of each contained respectively | | |
| Organic matters ... ... | 3·93 | 2·05 |
| Potash ... ... ... ... | 0·02 | 0·01 |
| Soda ... ... ... ... | 0·03 | 0·01 |
| Oxide of iron ... ... ... | 4·47 | 3·98 |
| Alumina... ... ... ... | 2·29 | 1·48 |
| Lime ... ... ... ... | 0·55 | 0·18 |
| Magnesia .. ... ... | 0·07 | 0·02 |
| Sulphuric acid ... ... ... | 0·05 | 0·01 |
| Phosphoric acid ... ... | 0·01 | 0·01 |
| Chlorine... ... ... ... | 0·02 | 0·02 |
| Silica (soluble in acids) ... | 0·35 | 0·12 |
| Carbonic acid ... ... ... | 0·46 | 0·16 |
| Insoluble siliceous matters ... | 88·22 | 92·33 |
| | 100·49 | 100·38 |
| Nitrogen per cent. ... ... | 0·11 | 0·09 |
| Water in the samples examined | 2·00 | 0·95 |

6. Surface soil 2·55, subsoil 2·45. (PROCESS IV.)

7 *Power of retaining moisture.* PROCESS (VI.)

1000 parts of surface soil retained ... 370 parts.
" of subsoil, " ... 342·5 "

*Rapidity of drying when exposed to the Air.*—In four hours $12\frac{6}{10}$ per cent. of the water imbibed by the soil, and $14\frac{}{10}$ per cent. of that taken up by the subsoil had evaporated. Mr. Cunningham reports that the soil is easily laboured, and that work may be carried on in two hours after the heaviest rain, without injury to the crops.

8. Light brown when moist, when dry grey.

9. Surface soil about 12 inches, subsoil from a few inches to several feet.

10. Docks, wild mustard, and in poor spots chick-weed, are the prevailing weeds.

11. Yields superior samples of wheat, oats, barley, beans, and grass. Wheat, in good seasons, averages 8 to 12, and barley 10 to 12 barrels to the statute acre, turnips and mangolds 20 to 30 tons, carrots 10 tons.

12. Fall of rain 40·20 inches annually; but this excessive moisture has not the same evil effects as on more impervious soils. Mr. Cunningham does not regard drainage as required. Rent 34s. per statute acre; labour 7s. per week; 2½ miles from Cork; roads good; limestone

abundant on the farm; no sea weed nearer than 8 to 10 miles; town manure easily obtained but not required; milk very rich, and the fat cattle and sheep highly prized by the butcher. Grass land contains much white clover and the fescue grasses. The soil does not appear adapted to the flax crop.

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### USE OF THE STANDARD TEST ACID IN ALKALIMETRY.

Each measure of the test acid prepared as directed at (69. *d.*) will contain 1·29 grains of absolute sulphuric acid ($SO_3$), and will be capable of neutralizing—

1·0 grain of *soda* ($NaO$).
1·71 grains of *carbonate of soda* ($NaO,CO_2$).
1·52 grains of *potash* ($KO$).
2·23 grains of *carbonate of potash* ($KO,CO_2$).

So that by multiplying the number of measures of test acid consumed in an alkalimetric experiment by the numbers placed opposite to any of the above substances, the amount of which we require to determine, the sum will represent the proportion in grains of the substance present.

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### RELATION OF THE DEGREES ON TWADDELL'S HYDROMETER TO THE SPECIFIC GRAVITY OF A LIQUID, IN COMPARISON WITH THAT OF WATER.

In bleaching and in manufacturing establishments the specific gravity of the leys, &c., employed is estimated by Twaddell's Hydrometer. As it is frequently required to ascertain the relation which the degrees on the scale of Twaddell bear to the direct specific gravity of the liquid, the following table will be found useful:—

| Twaddell. | Sp. Gr. | Twaddell. | Sp. Gr. | Twaddell. | Sp. Gr. | Twaddell | Sp. Gr. |
|---|---|---|---|---|---|---|---|
| 0 | 1000 | 50 | 1250 | 100 | 1500 | 150 | 1750 |
| 10 | 1050 | 60 | 1300 | 110 | 1550 | 160 | 1800 |
| 20 | 1100 | 70 | 1350 | 120 | 1600 | 170 | 1850 |
| 30 | 1150 | 80 | 1400 | 130 | 1650 | 180 | 1900 |
| 40 | 1200 | 90 | 1450 | 140 | 1700 | 190 | 1950 |

# APPENDIX.

## EQUIVALENT WEIGHTS AND SYMBOLS OF THE PRINCIPAL ELEMENTS.

HYDROGEN=1.

| | Symbols. | Equivalents. |
|---|---|---|
| Aluminium, | Al | 13·7 |
| Antimony, | Sb | 129 |
| Arsenic | As | 75 |
| Barium, | Ba | 68·5 |
| Bismuth, | Bi | 208 |
| Boron, | B | 10·9 |
| Bromine, | Br | 80 |
| Cadmium, | Cd | 56 |
| Calcium, | Ca | 20 |
| Carbon, | C | 6 |
| Chlorine, | Cl | 35·5 |
| Chromium, | Cr | 26·7 |
| Cobalt, | Co | 29·5 |
| Copper, | Cu | 31·7 |
| Fluorine, | F | 19 |
| Gold, | Au | 197 |
| Hydrogen, | H | 1 |
| Iodine, | I | 127·1 |
| Iron, | Fe | 28 |
| Lead, | Pb | 103·7 |
| Magnesium, | Mg | 12 |
| Manganese, | Mn | 27·6 |
| Mercury, | Hg | 100 |
| Molybdenum, | Mo | 46 |
| Nickel, | Ni | 29·6 |
| Nitrogen, | N | 14 |
| Oxygen, | O | 8 |
| Palladium, | Pd | 53·3 |
| Phosphorus, | P | 31 |
| Platinum, | Pt | 98·7 |
| Potassium, | K | 39·2 |
| Selenium, | Se | 39·5 |
| Silicium, | Si | 21·3 |
| Silver, | Ag | 108·1 |
| Sodium, | Na | 23 |
| Strontium, | Sr | 43·8 |
| Sulphur, | S | 16 |
| Tin, | Sn | 58 |
| Titanium, | Ti | 25 |
| Tungsten, | W | 22 |
| Zinc, | Zn | 32·6 |

## EQUIVALENT WEIGHTS AND SYMBOLS OF COMPOUND BODIES.

HYDROGEN=1.

| | | |
|---|---|---|
| Acetic Acid, ... ... | $C_4H_3O_3HO$ or $\bar{A}$,HO | 60 |
| Alum, ... ... ... | $\left\{\begin{array}{c} KO, SO_3, Al_2O_3, \\ 3SO_3+24HO \end{array}\right\}$ | 474·6 |
| Alumina, ... ... .. | $Al_2O_3$ | 51·4 |
| Ammonia, ... ... ... | $NH_3$ | 17 |
| —— Carbonate of, ... | $2NH_4O, 3CO_2$ | 118 |
| Ammonium, chloride of,... | $NH_4Cl$ | 53·5 |
| —— oxide of, ... ... | $NH_4O$ | 26 |
| —— Platinochloride of, ... | $NH_4Cl, PtCl_2$ | 223·2 |
| Arsenic acid, ... ... | $AsO_5$ | 115 |
| Arsenious acid, ... ... | $AsO_3$ | 99 |
| Barium, chloride of, ... | BaCl | 104 |
| —— silicofluoride of, ... | $3BaF, 2SiF_3$ | 419·1 |
| Baryta, ... ... ... | BaO | 76·5 |
| —— carbonate of, ... | $BaO,CO_2$ | 98·5 |
| Biborate of Soda,... ... | $NaO,2BO_3+10HO$ | 190·8 |
| Binoxalate of potash, ... | $KO, 2C_2O_3+3HO$ | 146·2 |
| Bitartrate of potash, ... | KO,HO $\bar{T}$ | 188·2 |
| Calcium, chloride of, ... | CaCl | 55·5 |
| Carbonic acid, ... ... | $CO_2$ | 22 |
| Chromate of Lead, ... | $PbO, CrO_3$ | 162·4 |
| Copper, protoxide of, ... | CuO | 39·7 |
| —— suboxide of, ... ... | $Cu_2O$ | 71·4 |
| Cyanogen, ... ... ... | $C_2N$=Cy | 26 |
| Ferrocyanide of potassium, | 2KCy, FeCy=$K_2$Cfy | 184·4 |
| ———————— containing water of crystallization, | $\left\{\begin{array}{c} 2KCy, FeCy+3HO \\ =K_2Cfy+3HO \end{array}\right\}$ | 211·4 |
| Fluoride of calcium, ... | CaF | 39 |
| Hydrochloric acid, ... | HCl | 36·5 |
| Iodide of palladium, ... | PdI | 180·4 |
| —— of potassium, ... | KI | 166·3 |
| Iron, protoxide of... ... | FeO | 36 |
| —— sesquioxide of (peroxide, ... ... | $Fe_2O_3$ | 80 |
| Lead, acetate of, ... ... | PbO,$\bar{A}$+3HO | 189·7 |
| —— chloride of, ... ... | PbCl | 139·2 |

| | | H=1. |
|---|---|---|
| Lime, ... ... ... | $CaO$ | 28 |
| —— carbonate of, ... | $CaO, Co_2$ | 50 |
| Magnesia,... ... ... | $MgO$ | 20 |
| Manganese, peroxide of,... | $MnO_2$ | 43-6 |
| —— protosequioxide of,... | $MnO, Mn_2O_3$ | 114·8 |
| —— protoxide of, ... | $MnO$ | 35·6 |
| Mercury, protochloride of, | $HgCl$ | 135·5 |
| —— protoxide of,... ... | $HgO$ | 108 |
| —— subchloride of, ... | $Hg_2Cl$ | 235·5 |
| —— suboxide of,... ... | $Hg_2O$ | 208 |
| Molybdic acid, ... ... | $MoO^3$ | 70 |
| Nitrate of lead, ... ... | $PbO, NO_5$ | 165·7 |
| —— potash, ... ... | $KO, NO_5$ | 101·2 |
| —— silver, ... ... | $AgO, NO_5$ | 170·1 |
| —— soda,... ... ... | $NaO, NO_5$ | 85 |
| Nitric acid,... ... ... | $NO_5$ | 54 |
| —— hydrated, ... ... | $HO, NO_5$ | 63 |
| Oxalic acid, ... ... | $C_2O_3$ | 36 |
| —— hydrated, ... ... | $3HO, C_2O_3$ | 63 |
| Phosphate of lime (bone earth phosphate),... | $3CaO, PO_5$ | 155 |
| Biphosphate of lime (soluble phosphate), ... | $CaO, PO_5$ | 99 |
| Phosphate of magnesia (pyrophosphate),... | $2MgO, PO_5$ | 111 |
| —— soda,... ... ... | $2NaO, PO_5$ | 133 |
| Phosphoric acid, ... ... | $PO_5$ | 71 |
| Potash, ... ... ... | $KO$ | 47·2 |
| —— bichromate of, ... | $KO, 2CrO_3$ | 148·6 |
| —— carbonate of, ... | $KO, CO_2$ | 69·2 |
| —— chlorate of, ... ... | $KO, ClO$ | 122·7 |
| —— chromate of,... ... | $KO, CrO_3$ | 97·9 |
| —— hydrate of, ... ... | $KO, HO$ | 56·2 |
| Potassium, chloride of, ... | $KCl$ | 74·7 |
| —— platino-chloride of,... | $KCl, PtCl_2$ | 244·4 |
| Silicic acid, ... ... | $SiO_3$ | 45·3 |
| Silver, chloride of, ... | $AgCl$ | 143·6 |
| Soda, ... ... ... | $NaO$ | 31 |
| Soda, carbonate of, ... | $NaO, CO_2$ | 53 |
| ——— containing water of crystallization,... | $NaO, CO_2+10HO$ | 143 |
| Soda, hydrate of, ... ... | $NaO, HO$ | 40 |
| Sodium, chloride of, ... | $NaCl$ | 58·5 |
| Strontia, ... ... ... | $SrO$ | 51·8 |
| Sulphate of ammonia, ... | $NH^4O, SO_3+HO$ | 75 |

| | | H=1. |
|---|---|---|
| Sulphate of baryta, | $BaO, SO_3$ | 116·5 |
| —— copper, | $CuO, SO_3+5HO$ | 124·7 |
| —— lead, | $PbO, SO_3$ | 151·7 |
| —— lime, | $CaO, SO_3$ | 68 |
| —— potash, | $KO, SO_3$ | 87·2 |
| —— protoxide of iron, | $FeO, SO_3+7HO$ | 139 |
| —— soda, | $NaO, SO_3$ | 71 |
| Sulphide of antimony, | $SbS_3$ | 177 |
| —— arsenic, | $AsS_3$ | 123 |
| —— copper, | $CuS$ | 47.7 |
| —— lead, | $PbS$ | 119.7 |
| —— mercury, | $HgS$ | 116·0 |
| —— molybdenum, | $MoS_2$ | 78·0 |
| Sulphuretted hydrogen, | $HS$ | 17 |
| Sulphuric acid, | $SO_3$ | 40 |
| —— hydrated, | $HO, SO_3$ | 49 |
| Sulphurous acid, | $SO_2$ | 32 |
| Tartaric acid, | $2HO, C_8H_4O_{10}$ or $\overline{T}$ | 150 |
| Tin, protoxide of, | $SnO$ | 66 |
| Water, | $HO$ | 9 |
| Zinc, oxide of, | $ZnO$ | 40·6 |

Explanation of the Tables.—By the term *element*, chemists understand a substance which has not been resolved into any simpler form. It has been found greatly to facilitate the description of the compounds formed by the union of these bodies, and of the changes which occur in chemical processes, to represent them by symbols, which, for the most part, consist either of one or two of the initial or characteristic letters of the Latin name of the substance. The numbers placed opposite to the names of the elements express the relative proportions in which they enter into combination with each other referred to, hydrogen taken as the standard, and regarded as = 1. Thus the number 16 which appears in the table opposite to sulphur (S.), expresses the fact that, 16 parts by weight of that element, combine with 28 parts by weight of iron (Fe. *ferrum*), and also with 100 parts by weight of mercury (Hg. *hydrargyrum*), and 1 part by weight of hydrogen (H.) These numbers also represent the quantities of each element which are found, by experiment, to be capable of replacing each other in combination, 28 parts of iron being equal in this respect to 16 parts of sulphur or 100 parts of mercury, and have, therefore, been termed *equivalents* of the substances (from *equus* equal and *valor* value.) The numbers placed opposite to the symbols of the compound bodies in the second table, also indicate the proportions in which these substances enter into combination, their equivalents being obtained by adding together those of their constituents; thus the equivalent of the element potassium ($K=39{\cdot}2$), added to that of oxygen ($O=8$), gives us 47·2 as the equivalent of the compound potash ($KO$). Organic acids are expressed by the initial letter of their names, over which a dash is placed, thus, $\bar{A}$ represents *acetic acid*, $\bar{C}$ *citric acid*. To express more than one equivalent of a substance, a number is placed either before or immediately after its symbol; when the figure follows the symbol it multiplies the number expressed by the symbol which precedes it; thus $SO_3$ signifies 1 equivalent of sulphur, combined with 3 equivalents of oxygen, and by the symbol $NO$ is meant 1 equivalent of nitrogen and 1 equivalent of oxygen, while $NO_5$ indicates also only a single equivalent of nitrogen, but in combination with 5 equivalents of oxygen.

When, as in the above examples, the symbolic letters are placed together without any intervening mark, it is understood that the substances represented exist in the most intimate form of combination, but when they are separated by a comma or plus sign, that the union is not of so intimate a character; thus $NaO$ signifies the close union which exists between the element sodium and the element oxygen in the compound body *soda*, but $NaO, NO_5$ expresses that the acid, nitric acid, $NO_5$, is not so firmly united to the base as the two elements of which the latter is composed. The sign + interposed between the symbolic letters, is employed to express a still less stable union between the substances which they represent; a large figure placed before the symbol of an element or of a compound, multiplies all the symbols which follow it, as far as the next comma or plus sign; or, when placed before several symbols, enclosed within a bracket, $3(NaO, SO_3)$ multiplies the compound which the symbols so enclosed express.

The proportions in which both elements and compounds enter into chemical combination being definite and unvarying, the tables, which contain the results of experiments, and are not to be regarded as merely theoretical conclusions, are of great practical value both in manufacturing operations and in chemical analyses (see *alkalimetry.*) Thus, if in the course of an analysis of bone dust, we have, by the addition of the ammoniacal sulphate of magnesia (65. VII. *b.*) obtained a precipitate, the weight of which when ignited is found to be 30 grains, in TABLE II. we find the equivalent of the compound produced, *pyrophosphate of magnesia*, which consists of 71 parts, or 1 equivalent of phosphoric acid, and 2 equivalents of magnesia, ($2\,MgO$), to be 111. To ascertain, therefore, how much phosphoric acid is indicated by the 30 grains obtained in the analysis, it is merely necessary to employ the following simple calculation :—

$$111 : 71 : : 30 = 19{\cdot}1 \textit{ phosphoric acid.}$$